Musical Gestures between Scores and Acoustics: A Creative Application to Orchestra

A Dissertation submitted to the faculty
of the University of Minnesota
by Maria Mannone
in partial fulfillment of the requirements
for the degree of Doctor of Philosophy

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1. Introduction

What do composers and conductors do?

The composer writes a score, and the conductor guides the orchestral performance.

The composer thinks of the sound he or she would like to obtain, listening to these sounds in his/her mind first. In order to lead musicians play the desired sound (or a good approximation), the composer thinks of the gestures that musicians should make, pitches in time, with loudnesses, timbres, and expressivity, inscribing symbolic indications. Orchestral musicians, due to their training, know which gestures, which specific movements in space and time to make, in order to transform the symbolic indications of the score into physical sounds. Musical gestures[1] connect two worlds, the world of the symbolic reality of the notational system, and the physical reality to which sounds belong.

The conductor reads beyond the simple symbolic indications, to find the character of the piece, searching for the 'added content'[2] to help orchestral musicians in being more expressive via better shaping and more refining their movements.

The conductor gives indications to the entire orchestra, time by time more focusing toward a specific instrumental section that has a predominant, or most difficult part in a musical passage. Each orchestral musician knows how to translate conductor's indications into specific instrumental gestures. Required gestures to make a violin

[1] There is a distinction between symbolic and physical gestures: the first are derived 'mechanically' from a score, with instantaneous changes of position from rest to playing/pressed key (instantaneous changes are impossible), and so on. Physical gestures are the real curves in space and time. While symbolic gestures usually present straight lines, physical gestures are always smooth.

[2] The added content I am talking about here is related to all the information not contained into the symbolic score, such as details on the expressivity, story of the composer, genesis of the composition, performing tradition. All these elements contributes to the potential in mathematical music theory of gestures, see [Mannone and Mazzola 2015, Mazzola et al. ToM III].

fortissimo will be different with respect to those required for a trombone *fortissimo*, but these movements have something in common[3].

A piano *tremolo* will have something in common with a timpani *tremolo*. A vocal *glissando* will have something in common with a string *glissando*. In fact, the human phonatory action in itself can also be studied in the frame of musical gestures as movements, systems of curves in space and time [Mazzola et al. 2017]. I'm interested in addressing such *gestural similarities*, and in using concepts of musical gestures in a creative way: not only to interpret a *given* score, but to *create* a new score. I've also been re-thinking some of my research between music and other disciplines, first of all physics and visual art, under the light as what I learned in musical gesture theory during my Ph.D. studies at the University of Minnesota.

Before coming to the US, I studied in Italy and France. During my training in Italy, alongside my curricular activities in theoretical physics and music, I had been on my own researching a possible way to translate image into music, via a tridimensional mapping of the main points of an object along the three axes of time, loudness, and pitch, leaving timbre as a free parameter [Mannone 2009, Mannone 2011]. This idea implied the use of simple concepts of mathematics as an intermediate language between different arts. It was an attempt to generalize the two-dimensional mapping of image into sound made by Iannis Xenakis [Xenakis 1971]. During my studies at IRCAM in Paris, I had been learning about other attempts of sonification: the creation of music as result of a mapping from something else, like data, urban landscape, and stellar maps [Adhitya 2011, Aphex Twin 1999, Surian 1995].

Next, I began reading the mathematical attempts to describe *gestures* [Mazzola 2007] in a kind of universalization of musical gestural communication[4]. Due to my personal interest in classical singing and opera, I tried to include the **vocal gesture** in the general theory. I also tried to **generalize** gesture theory to other instruments'

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[3] More formally, musicians are changing the shape of the gestural curves in space and time to transform a neutral gesture, or a *piano* one, for example, into a *forte* one. It means that both the violinist and the trombonist are applying what, with mathematical language, we call a *forte-operator* to transform their gestural curves [Mannone 2016].

[4]A general interest toward musical gestures may also be motivated by the origin of Western musical notation, early characterized by neumes, derived from the vocal / choir conducting gesture in Middle Age early Christian music and Gregorian Chant [Ward 1923].

playing, as well to **conducting**. This work, along with a detailed **mathematical** study of the transition from score-like gesture to physical gesture, and vice versa (from improvisation to written score), has been the main topic of the first two years of my Ph.D., in collaboration with Professor Guerino Mazzola [Mazzola et al., to appear 2017]. For such an analysis, the language was mathematical and physical. During this phase of my studies, I also started writing short pieces to apply theoretical ideas to musical composition, under the supervision of my composition Professor Alex Lubet. My dissertation piece, described in the following pages, is the natural consequence of such preliminary work.

My research now concerns the fusion of the fields of image-to-music mapping and gesture theory, allowing a more "scientific" and "gestural" *musicalization* of an object such as an olive branch or a nymphaea. The present work, my dissertation, *Fantasia and Fugue: Genesis of Music from Gestures*, is scored for chamber orchestra, piano, and soprano voice. It utilizes musical gesture unitarily and recursively as the nexus of its structure.

Fantasia and Fugue is in two movements.

The first movement, Fantasia, is a sequence of variations on gestures and their corresponding acoustical results, via progressive analogies and similarities. The movement builds gradually and constantly, starting with the voice, to which little by little orchestral musical instruments are added, following specific sound and gestural criteria.

The first gestures are inhaling and exhaling by the singer, voice glissandi and timpani glissandi, as well timpani high staccato notes and high staccato notes with the voice (made possible via a hitting-like diaphragmatic movement).

In the Fantasia, tremolo is associated with timpani and piano and vibrato with voice and strings. A two-note theme appears in different instruments.

In contrast, the Fugue is characterized by substantial thematic unity. The themes and their rhythmic variations are progressively transformed, for example, by shaping the subject inside the subject itself, as an inner recursion.

The themes are also varied using shapes based on physical images of real objects. Image is transformed into music via the tridimensional mapping described above.

Such transformations are aided by the concept of gesture, seen as a system of lines and trajectories, as the path of a pencil, or the movement of the eye observing an object.

In this work, images of a bay branch, an olive branch, and a nymphaea are translated into music and used to create new variations of subject and countersubject.

The underlying concepts behind my *Fantasia and Fugue* come from the mathematical theory of musical gestures [Mazzola ToM III 2017], my personal work on music and images [Mannone 2011], and some basilar concepts of fuzzy theory [Kosko 1993], graphic psychology [Nobile 2015], and human vocal physiology [Sundberg 1987]. More generally, we can make reference of crossmodal correspondences [Spence 2011].

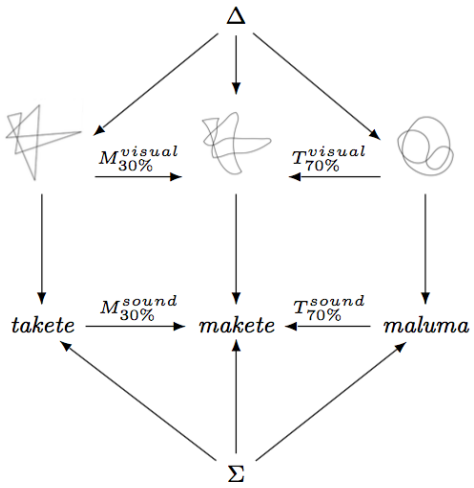

Figure 1

Uznadze first (1924), and Köhler (1929) then, proposed an experiment comprised of the presentation of two graphics, one with smooth lines, the other with angles. The person taking the test is asked to connect the two images with one of the two words "takete" and "maluma" respectively. These words do not have real meanings, but they are very different in terms of articulation. Most of the participants associate the first word with the angled image, and the second word with the smooth one. A recent study [Nobile 2015], between linguistics, acoustics and psychology shows an analogy between the angles and the explosive pronunciation of the dental "t" and of guttural "k", as opposed to nasal "m" and liquid "l", giving a plausible reason for this 'obvious' association. Figure 1 shows the original curves on the two sides, and a mixed curve in the middle. This mixed curve can be obtained applying a "smoothness operator" M to a takete image, or a 70% "angled-ness operator" T to a maluma image, may be called "makete" [Mannone 2016]. Similar operators act on words, giving the

“makete” as sound, as result of their action on “takete” and on “maluma”. The Greek letters in the diagram of Figure 1 indicate the abstract structure of the gesture. The use of percentages to express the degree of belonging, its approximation, is inspired by fuzzy theory [Kosko 1987], as opposed to the dichotomy of Aristotelian logic. The graphic uses arrows and spacial positioning to indicate relationships between objects —that are concepts in this case. The mathematical formalism that uses diagrams of points and arrows, satisfying specific properties, is derived from mathematical Category Theory [Lawyere 1997, MacLane 1975] and has been applied to Physics [Coecke 2015] and Music [Mazzola ToM 2002]. A more flexible use of diagram on the base of philosophic thinking often appears in the contemporary school of philosophy of science in Paris [Alunni 2004, Châtelet 1993].

Sounds, images, abstract concepts, connections between them: may we envisage a connecting element? We may talk about cases of similarity of gestures between sound production in terms of singing—and also diction, and images. There was a similar position on the basis of my book on music and image [Mannone 2011], but there I was not yet discussing gestures, see Figure 2, with the beginning musical orchestral score derived from the Sagrada Família[5] [Mannone 2011; Mazzola, Mannone and Pang 2016]. More generally, artistic expressivity can also be approached in terms of what I called “gestural similarity” [Mannone 2016]. Let me explain this concept. Non musically trained listeners enjoy music when it transmits ‘emotions’. What does this mean? It means that music, carrying abstract gestural content, is perceived in gestural terms. For example, soft music may carry the content of a caressing gesture, giving a pleasant feeling. Conversely, striking music makes people[6] think of a striking gesture, with a feeling of power, or violence[7]. In the following pages, I will analyze in more detail the mechanism of construction of the Fantasia and of then Fugue. Graphic visualizations are used to illustrate the concepts.

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[5]The idea of correspondences between pitches and images is supported by some psychology studies, as about high pitched sounds and elevation movements (Roffler and Butler 1968).

[6] This can open a discussion about “universal” in art. In my opinion, this may also depend on the cultural background of listeners.However, the deepening of such a discussion is beyond the purview of this work.

[7]Analogies between sound and movement, especially in movies, are discussed in literature [Zbikowsky, 2002]

My present research looks to the expressive potentialities of music, the applicability of mathematical language, and the dream of conciliation between different and separated fields to catch the mathematical nucleus in each physical reality, as well as music hidden inside each body of physics, and sound acoustics as the final result of thinking via images and analogies. I hope and wish to dedicate my future career to such a fascinating universe.

I would like to manifest my esteem and my gratitude toward the precursors of these interdisciplinary studies. Some of these people have been my teachers. As an incomplete list, I can mention Marco Betta, Salvatore Sciarrino, Guerino Mazzola, and Dave Benson. A special thanks to the memory of Pierre Boulez, whom I met once at IRCAM, and who showed his encouragement and enthusiasm toward my interdisciplinary activity, especially my project, "La Ville Pulsante." I'm also very grateful toward all the music and science scholars that supported me in my interdisciplinary work, both in Europe, between Palermo and Paris, and in the United States, at the University of Minnesota: in geographic order, Giuseppe Compagno, Emilio Fiordilino, Franco Gelardi, Moreno Andreatta, Carlos Agon, Michèle Castellengo, Mikhail Malt, Michèle Scharapan, Charles Alunni, Mikhail Shifman, Alex Lubet. In particular, professor Dr. Alex Lubet is my adviser for Ph.D. dissertation: thank you, Alex!

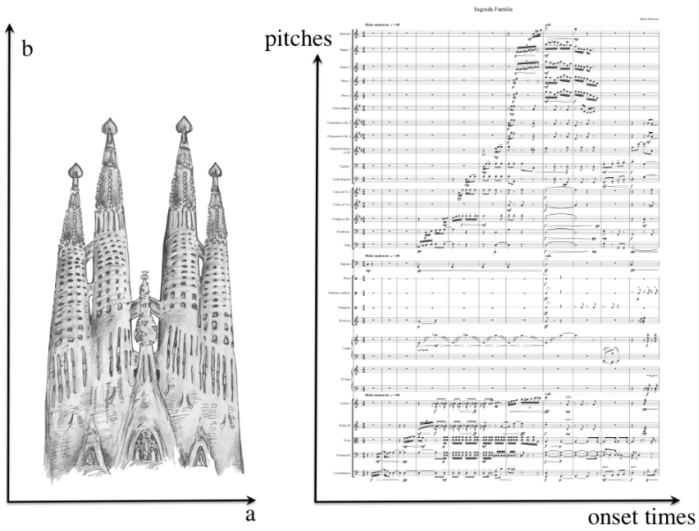


Figure 2

2. The Piece: “Genesis of Music from Gestures”

2.1 First Part: Fantasia

The first movement is in the form of gestural variations almost as improvisations. The concept of gestural similarity is used to connect these variations.

The entire orchestral sound is built from the voice, and the vocal emission is preceded by breathing (written in the score), as in the following fragment of the beginning, measures 1-5 (Figure 3).

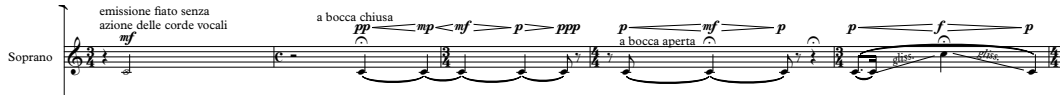


Figure 3

This is the order of appearance of instruments:

Voice: Breathing, Glissando, Staccato, two-note theme (from measure 1);

Percussion: Staccato, Glissando, tremolo (from m. 10);

Piano: two-note theme, tremolo (from m. 28);

Strings, tremolo, complete theme (from m. 34);

Winds with Voice, melodic sequence, Legato (from m. 46);

Brass, two-note theme (from m. 106);

End: voice alone (mm. 80-82).

2.1.1 Voice to Start

The movement starts and ends with voice alone—and the Fugue, in the last bars, does the same. Why start with voice? To my mind, a primitive, simple approach to music might use voice and a rhythmic gesture. The voice can have a rhythmic valence as well a percussive one: a hit of the diaphragm is very often used by classical singers to make high staccato notes. Voice as melodic contour and rhythm have one thing in common: events in time. Breathing is the necessary, preliminary condition for vocal emission. The rhythm also needs silence to make distinction between the events in time.

In my *Fantasia and Fugue*, the initial and final gesture is breathing. The *Fantasia* starts with breathing, and the *Fugue* ends with the singer's breathing.

Human phonatory system

The human phonatory mechanism is composed by three main functions and parts:

1. The 'compressor,' source of energy—air pressure, is given by the diaphragm (Figure 4);
2. The production of the sound that happens in the larynx (Figure 5), a system of muscles and cartilages in the throat, containing and determining the changes of length and shape of the vocal folds;
3. The filter, with the vocalic specialization, that involves the upper resonators: above the vocal folds, the mouth space and the noise space (the 'mask'), Figure 6. The following images, respectively, represent the diaphragm, the larynx (the angle represent the rocking of the larynx, and the opening-closing of the vocal folds), and the muscles of vocal folds, and their position in the human head.

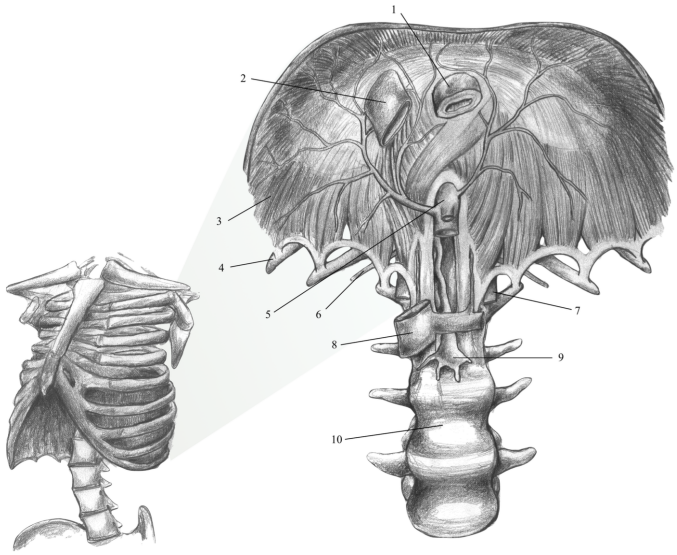


Figure 4. On the left, the position of the muscle diaphragm among the ribs; on the right, the detail of the diaphragm, constituted by three crossing muscular folds, as the closer other parts of the human body: 1: esophagus, 2: inferior vena cava; 3: one of the muscular tissue; 4: ribs; 5: aorta; 6: anamostosis between azygos vein and vena cava; 7: right ascendent lombar vena; 8: inferior vena cava; 9: cisterna chyli; 10: spine.

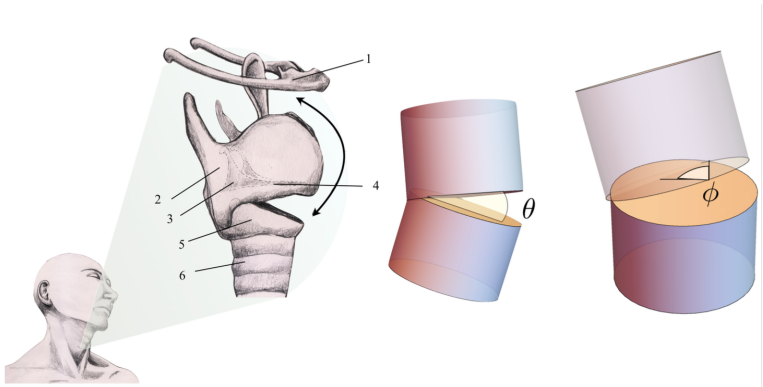


Figure 5. Detail of larynx cartilages. Left, position of the larynx in the human neck. Details of the larynx: 1: hyoid bone; 2: thyroid cartilage; 3: arytenoid cartilage; 4: vocal folds; 5: cricoid cartilage; 6: trachea. Middle image: angle θ of the larynx with respect to the trachea, and right image: angle φ between the two vocal folds. It reminds to spherical polar coordinates. A third coordinate ρ can be envisaged in the length of the vocal folds.

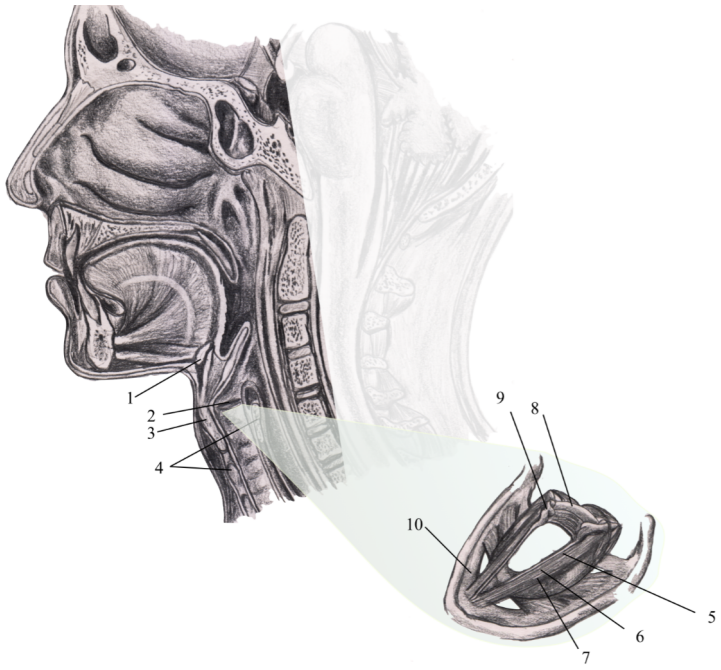


Figure 6. Section of the human head showing the larynx. 1: hyoid bone; 2: vocal folds; 3: thyroid cartilage; 4: cricoid cartilage. Details with muscles of vocal folds: 5: vocal ligament; 6: vocalis muscle; 7: thyro-arytenoid muscle; 8: cricoid cartilage; 9: arytenoid cartilage; 10: thyroid cartilage. The phonation is produced by the movement (the gesture!) that alternately brings together and moves apart the vocal folds between themselves.

Recently, vocal gestures have been included in the frame of mathematical gesture theory [Mazzola et al. 2017]. The production of a precise sound with a particular pitch, intensity and timbre, requires a specific combination of physiological parameters of the phonatory system that the singer needs to handle. A combination of physiological parameters leads to a specific spectral result, in terms of acoustics. This is the gestural definition of vocal emission in a nutshell.

2.1.2 The same technique among different musical instruments: similarities

Voice can make a legato, and this can be compared with a string legato. Voice and strings can have vibrato in terms of short and quick pitch variation, or not. A flute can also play vibrato or not, in terms of rapid changes of intensity (more perceived) and (slightly) of pitch, less perceived[8]. When we record a singer, a violinist and a flutist playing vibrato and non vibrato, we may analyze and compare their sound

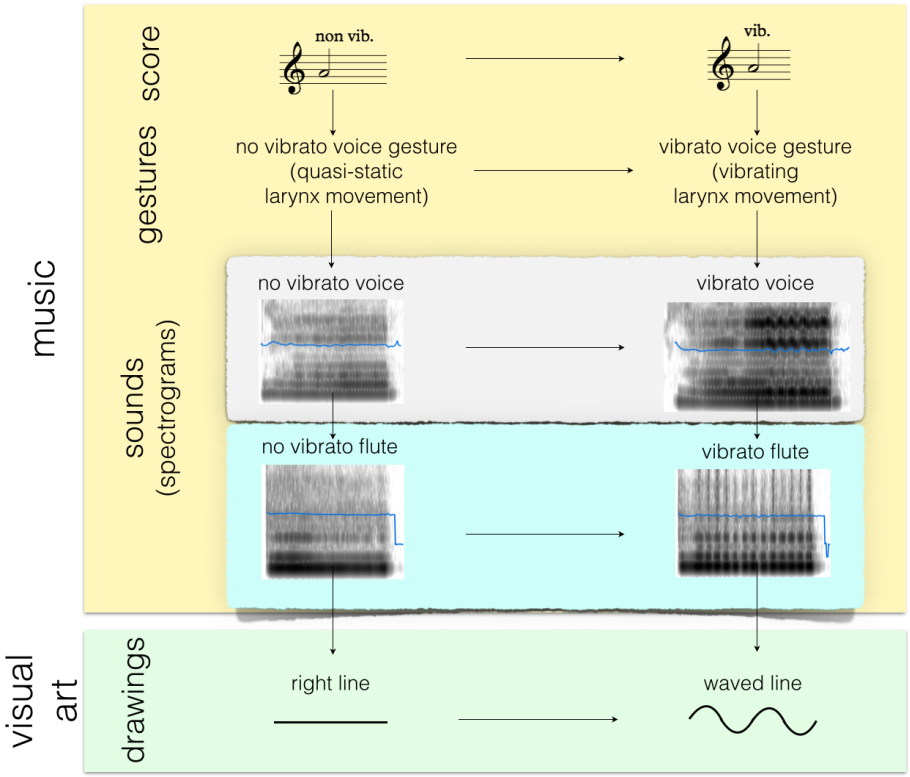


Figure 7

production via spectrograms, graphs showing the harmonics in the sound and their variation with time, characterizing the timbre. We can see that there is an analogy, also graphic, between the vibrato for a singer, a flutist and a violinist, and, correspondingly, a similarity between the non vibrato of these musicians. Thus, we

[8]Empirically, it seems that vibrato on flute is not on pitch, because we can make vibrato without changing the position of fingers and lips, but only, but slightly, changing the air pressure—and so the loudness—on the same note. However, quantitative studies [Meyer 2009] show that there is also a pitch variation. The spectrogram of the voice vibrato does not have white spots (no change in intensity or silence), but up-down with the frequency. In the flute spectrum, the several gray spots corresponds to the variation in intensity, and the blue line highlights the little pitch variation.

can make the diagrams of Figure 8 and 9. In general, in such a diagram, it is not always possible to follow one or another path and reaching the same object. However, in the cases we will consider here, it is possible[9]. It is not working when, for example, we electronically create a sound that is impossible to be played by a real performer on an acoustic instrument. In this case, there is no human gesture on acoustic instruments to get that sound.

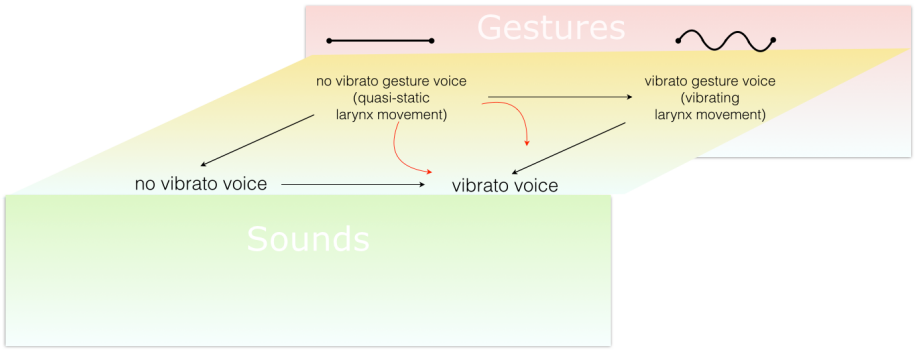


Figure 8

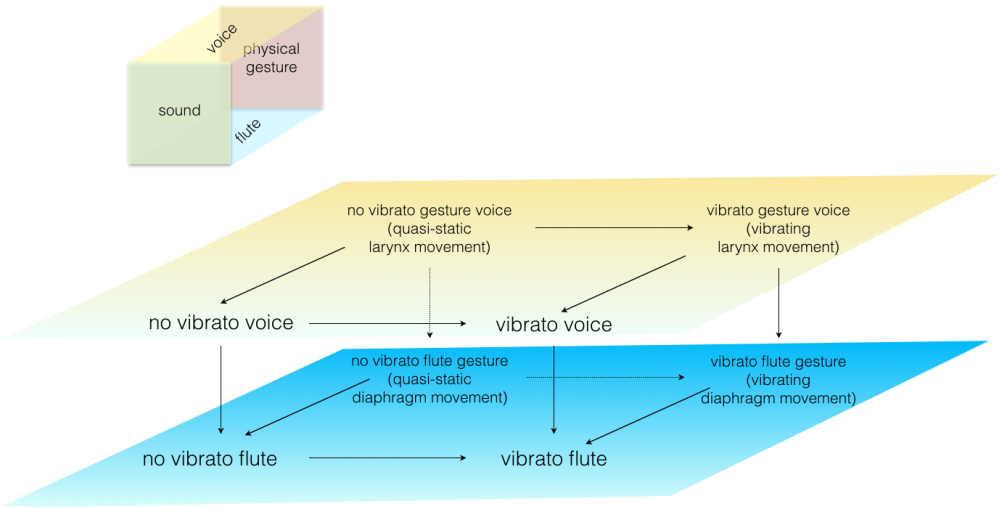


Figure 9

[9]We say that a diagram is *commutative* when we can interchangeability follow one or another path.

We can choose a simple graphic representation to exemplify the difference between vibrato and non vibrato. Even non-musicians would agree for the representation of Figure 10: a straight line versus a waved one.

We can make a similar comparison, for example, with tremolo for timpani and for piano, and a comparison between tremolo and vibrato.

This idea of gesture similarity in terms of articulation techniques is at the base of the Fantasia. The instruments start playing according to these principles of similarities. In this sense, the gesture becomes a thematic element.

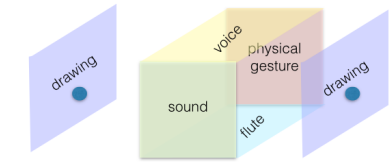
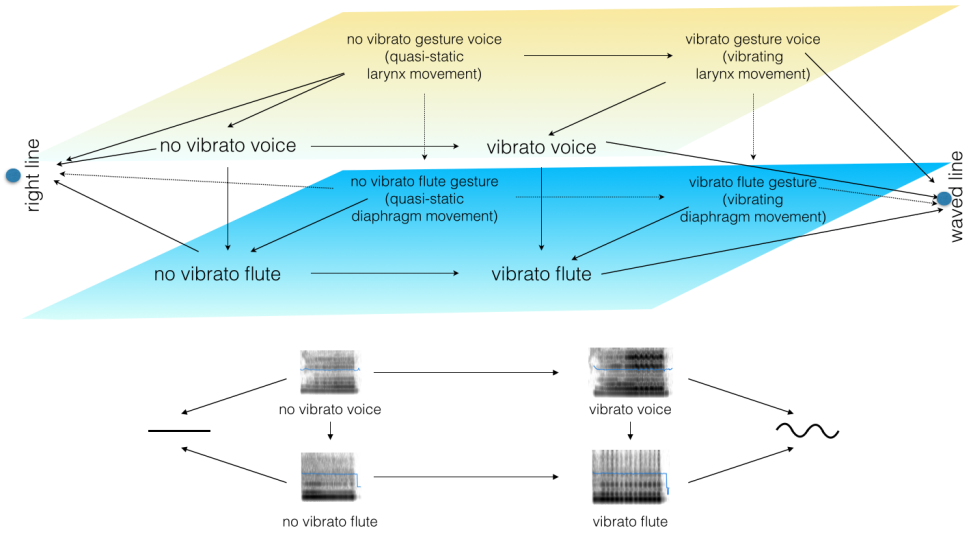


Figure 10



Example of two-note theme between voice and piano, mm. 32-34 (Figure 11):

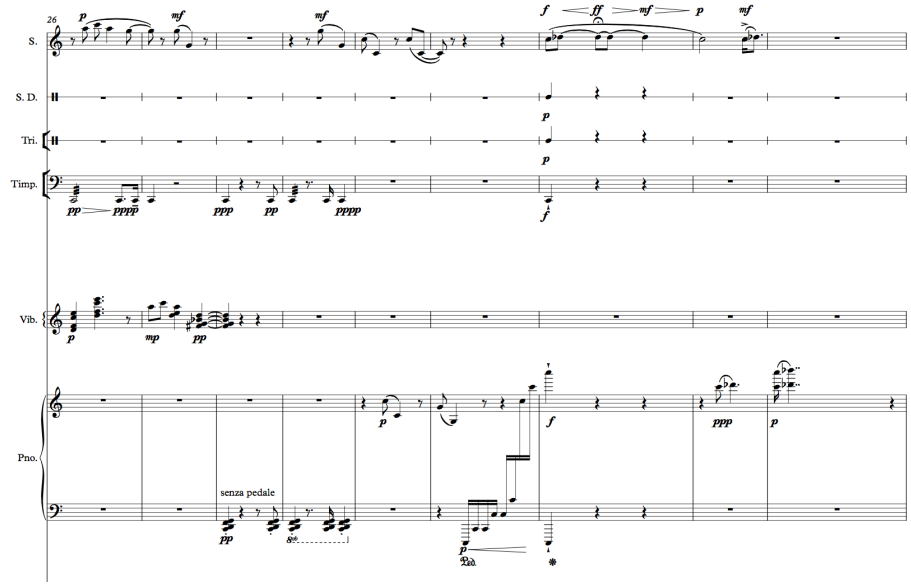


Figure 11

Tremolo piano and tremolo timpani, mm. 36-41 (Figure 12):

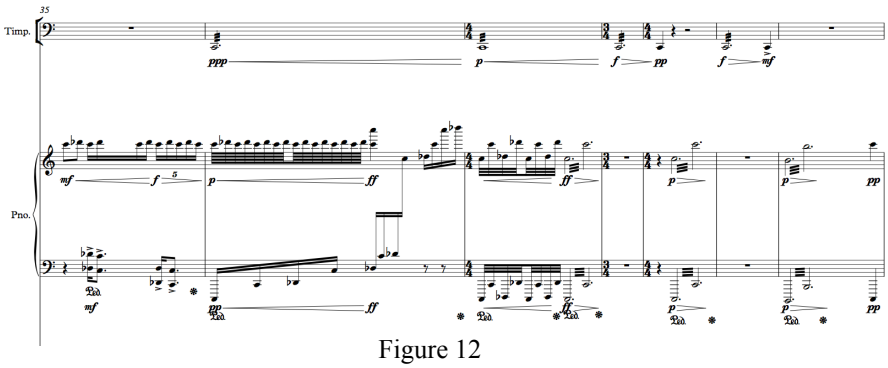


Figure 12

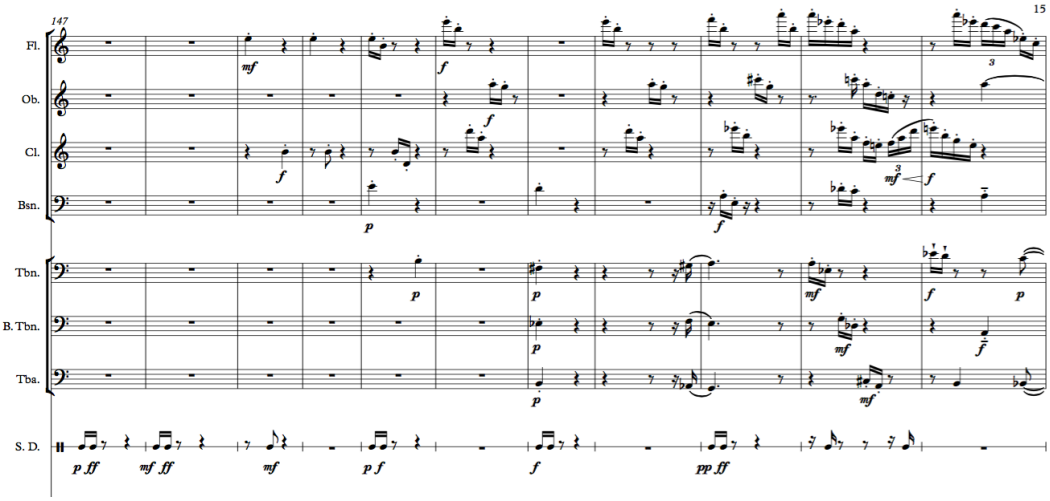


Figure 13

Similar articulation among instruments, and generation of music from a single cell, mm. 147-157 (Figure 13):

Ending with the voice alone, mm. 80-82 (Figure 14):

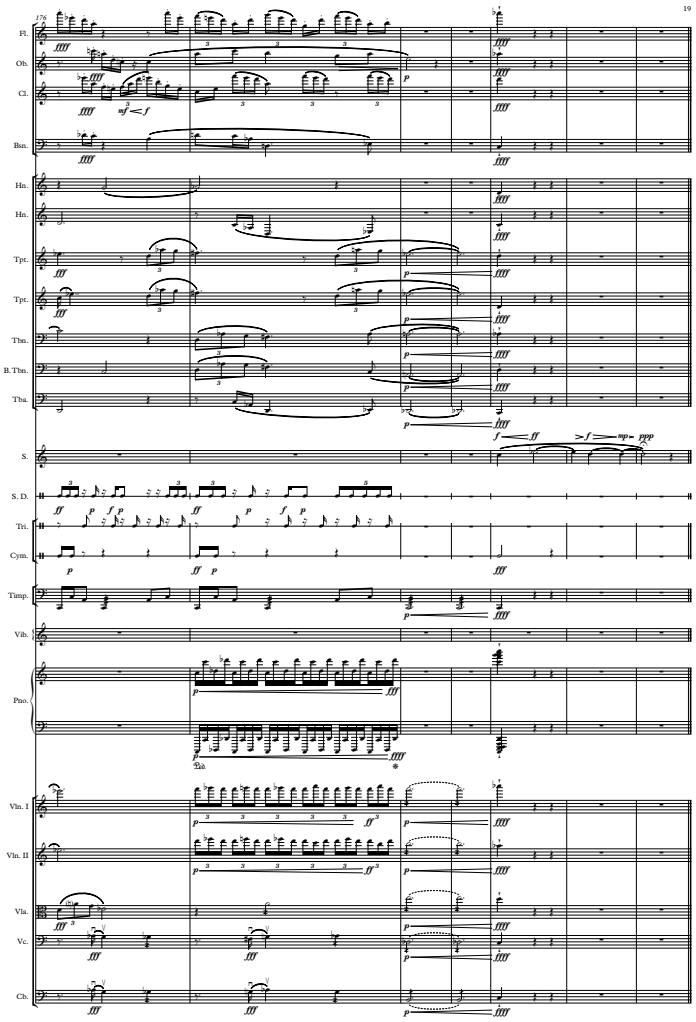


Figure 14

2.2 Second Part: Fugue

The second movement is a fugue. I applied here a main concept from mathematical theory of musical gestures, the hypergesture (that is a gesture of gestures), as well a way of creating music from visual images, and the combination of the two. We will analyze the details in few examples. The structure of the movement is the following:

Exposition: Percussion first, then other instruments;

I Divertimento: Bay Branch

(image to music via gestural similarity);

I Reprise: Theme Shaped with Bay Branch;

II Divertimento: Olive Branch;

II Reprise: Theme shaped with Olive Branch;

III Divertimento: Nymphaea;

III Reprise with Stretti: Theme shaped with Nymphaea;

Pedale: diminuendo; ending with the initial gesture (breathing).

The beginning of the fugue, with the subject (highlighted in red) and countersubject (highlighted in blue) played by percussion in their original rhythmical shape is shown in Figure 15 (mm. 1-11):

Figure 15

The subject played by the double basses with a rhythmical variation, with the answer played by celli, melodically modified (Figure 16, mm. 23-27):

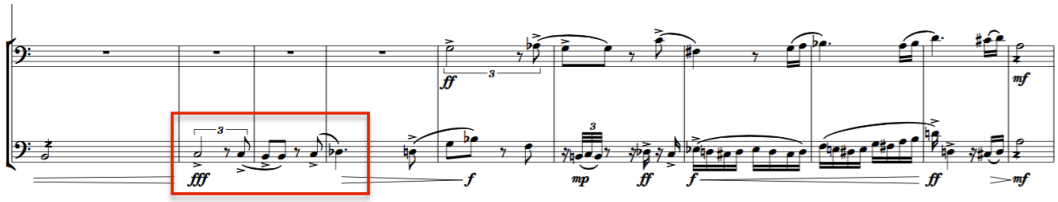


Figure 16

Variation of the rhythm of the subject at the end of the Exposition, see flute part (Figure 17, mm. 66, 67), where we have the variated head of the subject (red) and its rhythmical diminution (orange). In particular, this passage has been obtained putting the subject inside itself, as it will be explained later.

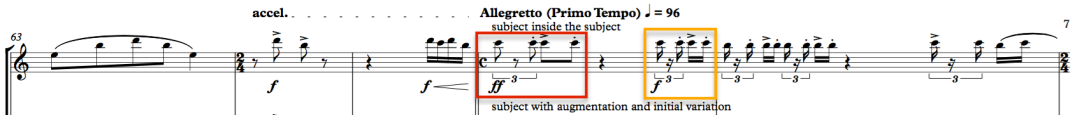


Figure 17

The two final pages of the fugue, with the last *stretti* followed by a general *diminuendo* and the conclusion of the piece, ending with the solo vocal gesture—in analogy with the opening and closing of the Fantasia, are shown in Figures 18 and 19.

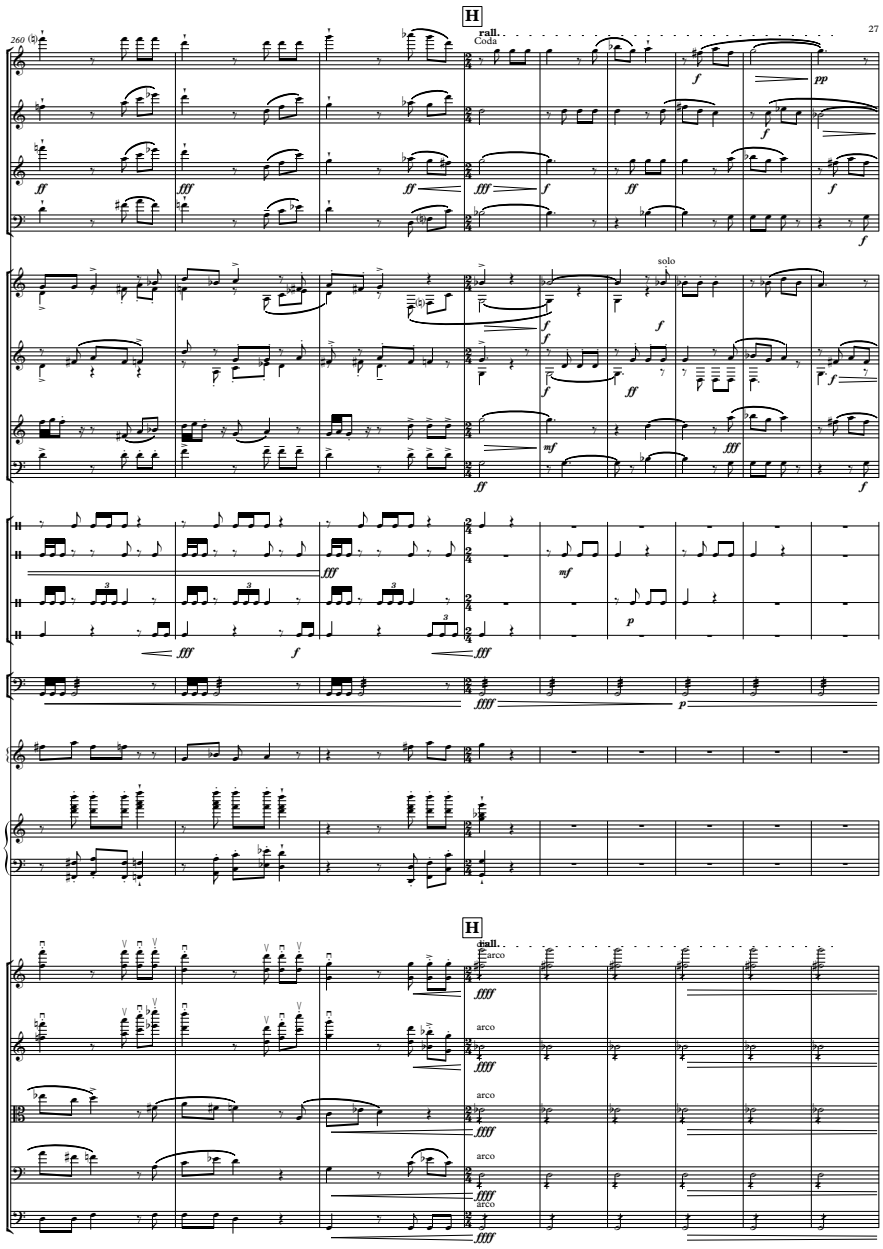


Figure 18

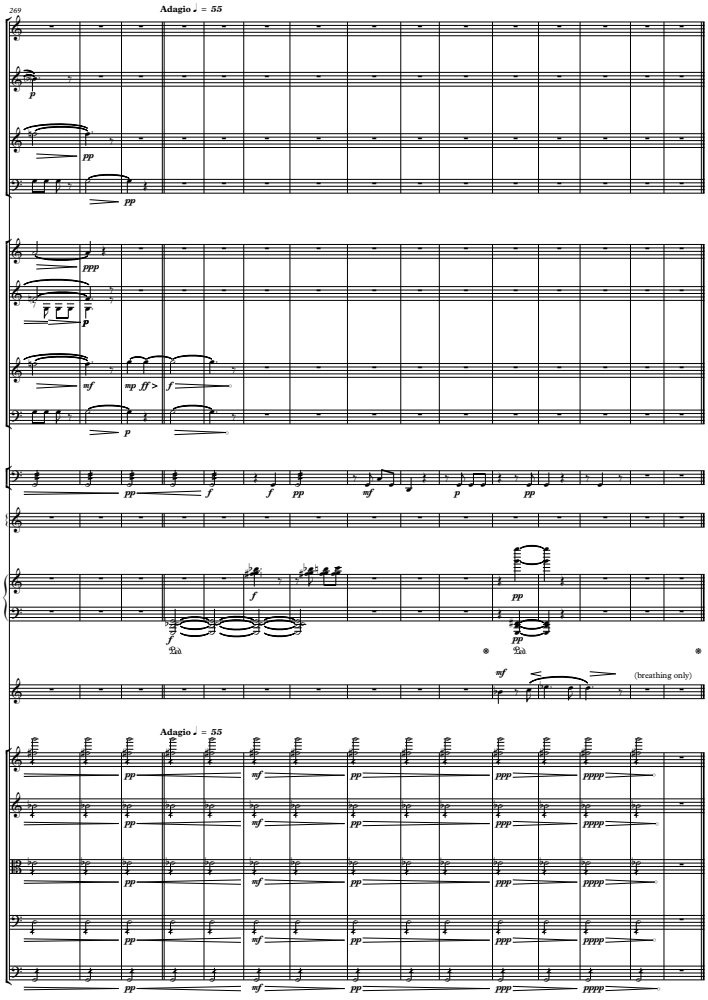


Figure 19

2.2.1 Concept of hypergesture, and its application to variate subject/ countersubject

A gesture can be defined as a mapping from a system of abstract points and arrows to a system of continuous curves in space and time. (We have again points and arrows from category theory, but they are transformed into points and arrows in space and time, as true objects of physics instead of purely abstract math.) The first is called *skeleton*, the second *body* [Mazzola and Andreatta 2007]. A curve in space and time is, for example, a path of a finger through the tridimensional space, and during time, a trajectory containing time information.

A gesture of gestures is a hypergesture. What does that mean? Consider a circle. If this circle moves along a straight line, we get a tube, a line of circles. If our circle moves alongside a bigger circle, we get a curved tube, a "circle of circles." A scale played at the piano is another example of hypergesture: an horizontal movement through the keyboard (imagine a horizontal line as trajectory), and each "point" of this line contains the movement of pressing a key.

We can envisage a similar structure in other fields. For example, in biology, a dorsal spine can be represented as a line, that is constituted by vertebrae: a line of bones. In principle, the hypergesture is continuous, but we can also think about "discrete" examples, as the spine, or the piano glissando. A tube is continuous, while a collection of circles, as a set of circular bracelets, is discrete. A piano glissando is discrete, a glissando with violin is continuous. A movement in real life is continuous, while a collection of partially superimposed pictures, as isolated photograms, (chronophotography) is discrete. However, it is a powerful tool to approximate continuous movement.

In the same way, we can make a circle having circles in each point, we can think of a musical theme where each "point" can be itself a theme. I used this tool to put the subject inside the subject, as in an inner recursion. For example, each note of the subject can be augmented and split into several notes, with the rhythm of the subject.

Given these ideas, the classical structure of the fugue is here revisited in a modern and experimental musical context, and an extended counterpoint used as compositional tool. We may say that the knowledge of the past can guide the future. For this reason, the study of classic forms can enhance musical creativity of new works.

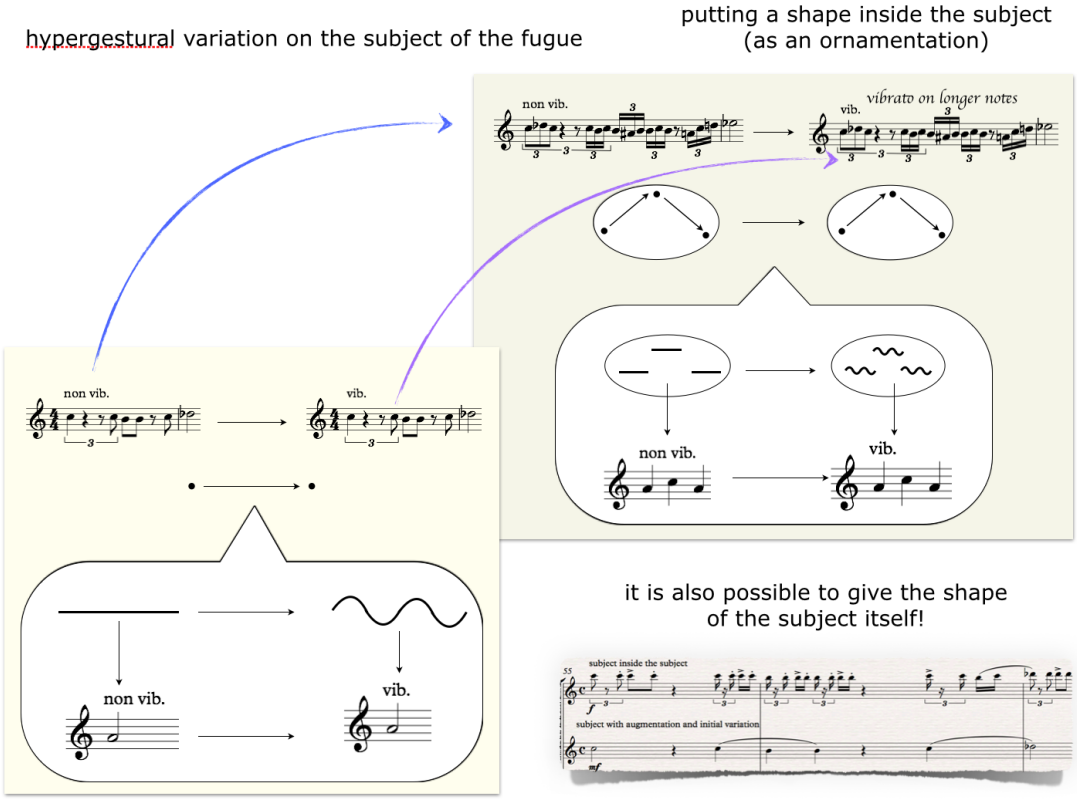


Figure 20

2.2.2 Music from Images, combined with gestural concept

Music can be inspired by visuals. May music be *derived* from images? Can images be *derived* from music? That was my question in 2009. Italian composer Salvatore Sciarrino [Sciarrino 1998] analyzed orchestral scores in two-dimensional diagrams, indicating pitch and time, and using colors to make distinction between timbres, and thickness of lines to characterize loudnesses. Another Italian composer, Marco Betta, used tridimensional graphics, where one of the axes was meaning loudness [Mannone 2011]. Greek composer, architect and scientist Iannis Xenakis [Xenakis 1971] had proposed the use of tridimensional graphics to analyze timbre. He also made a technological device, the UPIC tablet, to sonify two-dimensional images, in terms of pitch (vertical axis) and time (horizontal axis). Research and attempts at sonification of data are relevant [see bibliography of Mazzola, Mannone and Pang 2016]. In 2009, I tried to generalize the UPIC idea using tridimensional graphics, making the 'vice versa' of Betta's technique to analyzing scores. In a nutshell, each point of a tridimensional object can be mapped into three axes, loudness, time, and pitch (see Figure 21: the Duchamp's *Bicycle Wheel* can be sonified by projecting a selection of its points in the time-loudness-pitch tridimensional space, t I ν in the image).

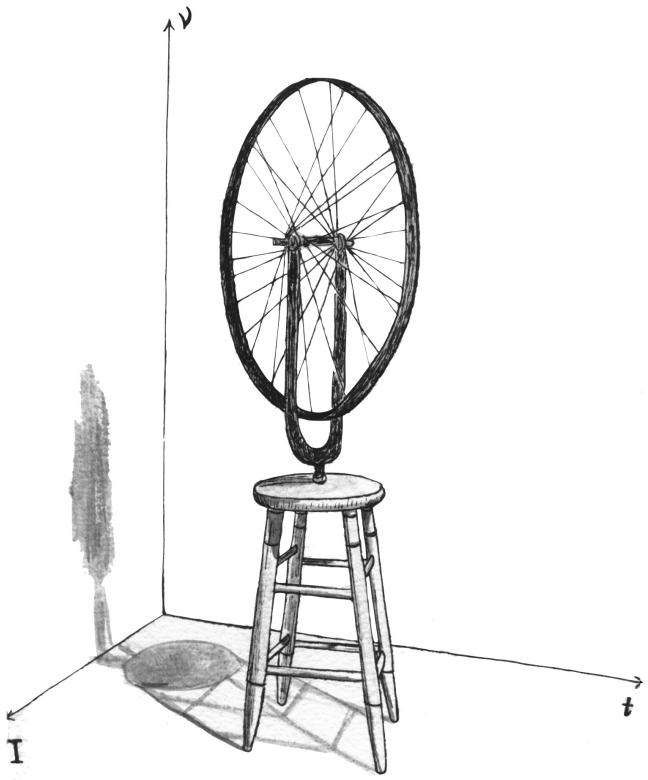


Figure 21

I made some examples by hand, and, years later, using the computer for the translation of space coordinates into sound [Mannone 2011]. Of course, it was necessary to effect a selection of points, in order to avoid clusters that would make confusion and render unrecognizable the shape. I started to re-think my idea of *tridimensional music* reading studies about mathematical gesture theory [Mazzola 2007] and working on this field [Mazzola et al. ToM III]. I found that better examples of such a transformation required another condition, that we may call *gestural similarity* [Mannone 2016]. For example, a musical rendition of a perforated canvas by Lucio Fontana should also take into account the *gesture* of making a hole—seeing visual arts, as painting or drawing, as the *result* of a gesture. It is a similar gesture to a pianist playing a staccato, or a violinist playing a *balzato*/*pizzicato*/*molto staccato*, a singer making a *staccato* and *forte* sound with a hit of the diaphragm. In my first book [Mannone 2011], I describe, among the examples, a musical piece I derived from from *Concetto Spaziale* by Lucio Fontana, see Figure 22. To render the not-round shape of a hole in the canvas, and the irregular and protruding border of the piece of canvas on the back side, I used the *acciaccatura* for each note in the score.

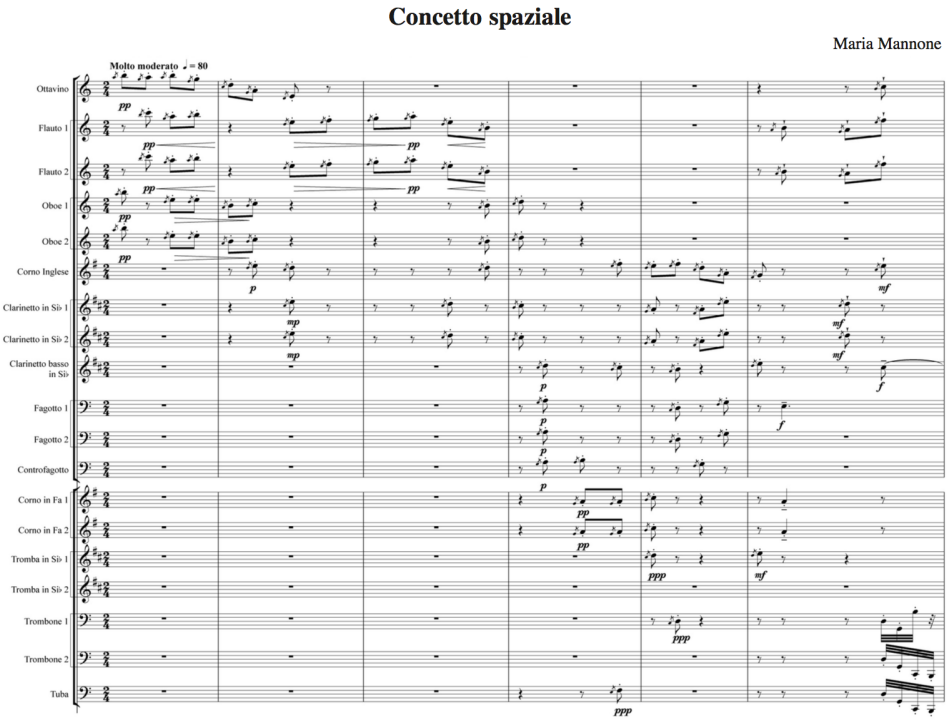


Figure 22

Between musical gestures and visual gestures, as well as between music and emotion, and gesture and emotion, of course, there is not a one-to-one correspondence. However, in my opinion, there are some 'shared' nuclei of contents. The mathematical theory that express this non-precise membership, and the degrees of inclusion, is the *fuzzy logic*. In Aristotelian dualistic logic, either A is in B, or not, true or false. In fuzzy logic, A can stay to B with some degree: totally included will lead to a 100%, halfway 50%, very few included, 10%. In fuzzy logic, there are *degrees* of truth. For this reason, it seems appropriate to use fuzzy thinking while approaching degrees of truth and different things, as images, sounds, numbers, equations, gestures are ontologically different. Fuzzy logic had already been applied to studies of music and emotion by scholars of the Stockholm group [Friberg 2004].

In my *Fantasia and Fugue* I chose a bay branch, an olive branch and a nymphaea to shape the themes and variations. They are not gestures, of course, but we can think of their **shapes** as the **results of drawings**; as we attempt to draw them. Why these specific images? The reason is that they are easily recognizable shapes, simple but they are also archetypical. More complex shapes can be derived from these simple shapes. Moreover, the method developed for a simple shape can be extended to more complex shapes. In art as in science, when possible, the starting point must be something simple and easy to handle. Finally, these three natural objects are parts of living beings and traditionally have carried symbolic content. Bay symbolizes knowledge, olive peace, and nymphaea purity. Symbolic contents hidden in music and musical structures, even with the aid of correspondence between number and ideas (as in the Gematria[10]), were strongly used in classic counterpoint. In the following, I will only focus on the bay branch and nymphaea flower, because the musical mechanism underlying the olive branch is similar to the one required for the bay branch, see Figure 23.

To extract the theme from a bay leaf, software Mathematica has been used. A leaf has been schematized as an upper curved line, and a lower curved line, with

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10W. Zeitler, *Musical Gematria*, 2012, http://www.williamzeitler.com/media/MusicalGematria.pdf
https://prezi.com/3fo1tdjcuutr/copy-of-numerology-and-symbolism-in-the-music-of-johann-sebastian-bach/
https://en.wikipedia.org/wiki/Gematria

common initial and endpoints (two portions of sinusoids). The idea of the branch has been musically made via transposition to upper tones of the leaf's melodic contour. The technique to musically make the olive branch is similar, but here Mathematica has not been used being superfluous. The same applies to the petals of the nymphaea.

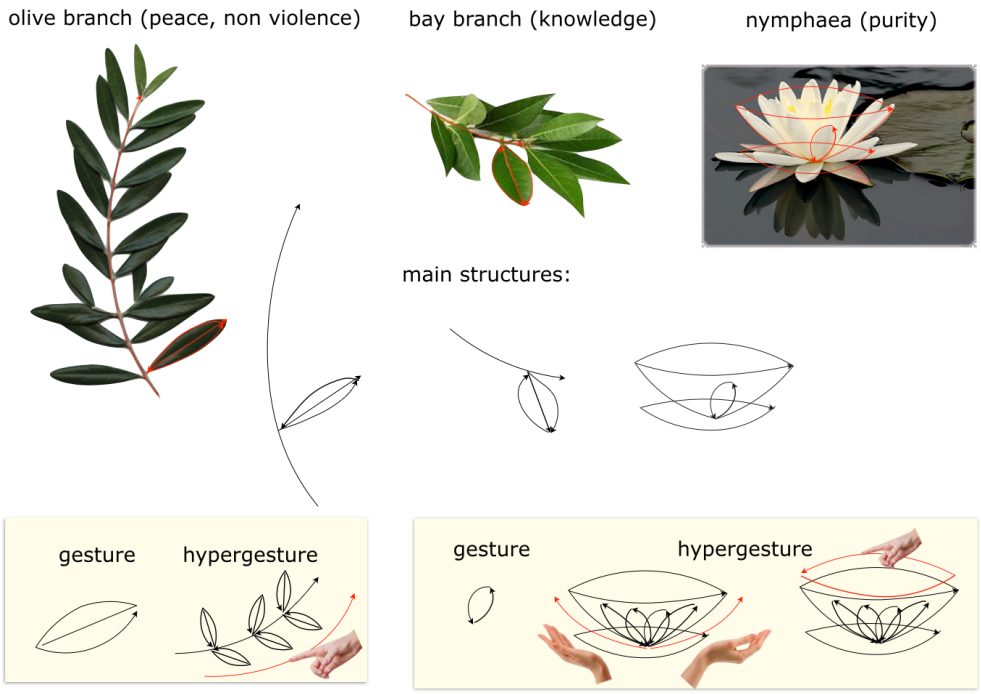

Figure 23

Later, we will discuss the musical rendition of the rotational shape of this flower. The following musical excerpt shows the main notes of the upper melodic contour (C G Bb G C) and lower melodic contour (C D D F C) of one leaf, and the first transposition, played by the winds, see Figure 24.

The subject can be modified according to the structure of the bay branch, see Figure 25. The notes for the upper side of the leaf are C, G, B flat, G, C. Each note is augmented in duration, and split between several notes, that, together, give the (simplified) rhythm of the subject. In the same musical example, there is an analog variation that uses the rhythm of the countersubject. It is just one way to shape the themes according to some material coming from visuals.

As noted above, the repetition of a leaf moving along the branch is musically made with a (discrete) transposition. However, there is a section, in the piece (mm. 131-132), where the leaves are not connected via a discrete transposition, but a *glissando*. A glissando gives the idea of a continuous transformation. In Figure 26, the red highlighting indicates the notes of the first half leaf, the blue highlighting of the transposed one. Squared highlighting indicates the example with discrete transformation, while curved ones, the example with continuous transformation.

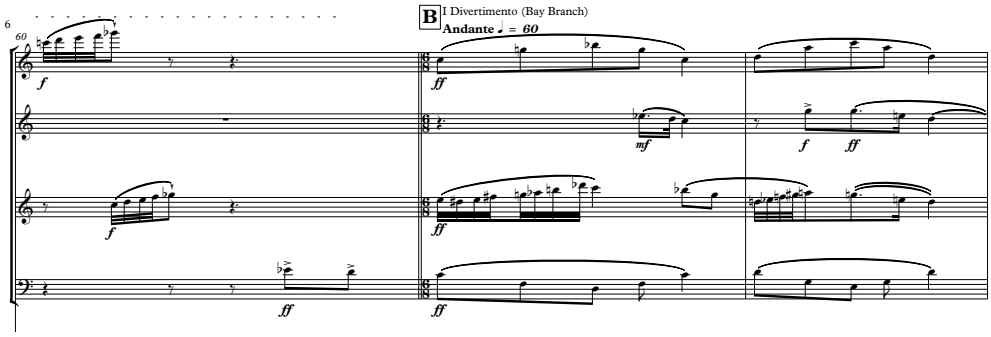

Figure 24, Fugue, measures 60-62, winds —flute, oboe, clarinet in B flat and bassoon.

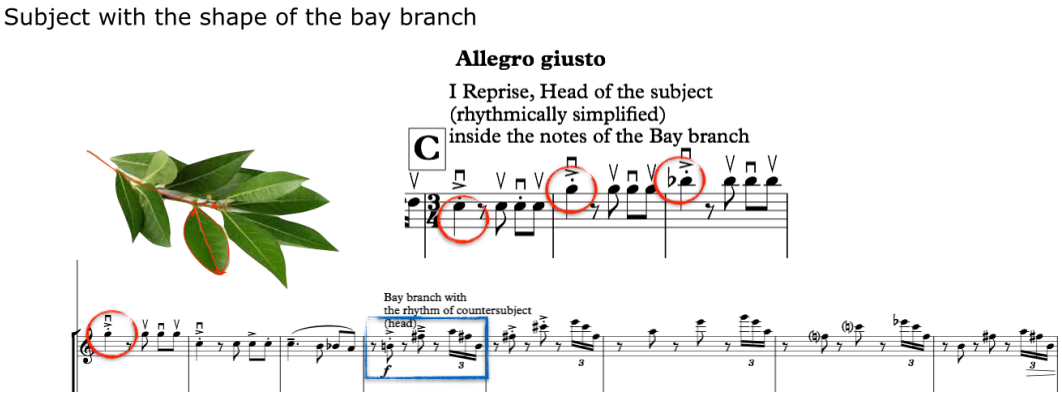

Figure 25

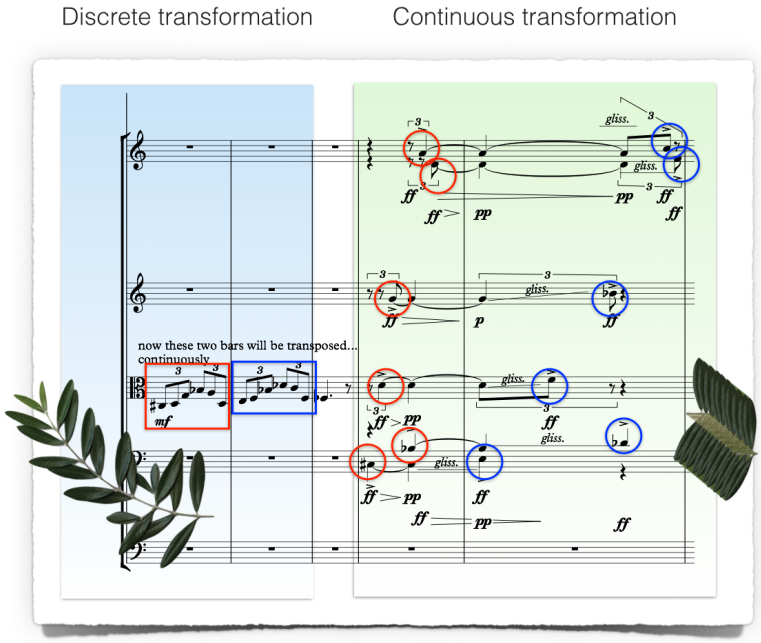

Figure 26

The exploration of continuous transformation has a theoretical underpinning in itself, due the continuous nature of the hypergesture. We can see discrete transformation as in step-by-step photography, a *discrete sampling* as signal treatment. Regarding movement and periodic shape of vegetables: there are two concepts we may make reference. The first is chronophotography. There are famous examples from the French photographer Étienne-Jules Marey. Partly superposed photographs, quickly taken, to give the idea of movement. When we have real photograms, and we see them so quickly as to be unable to distinguish between them, we have the illusion of real, continuous motion, as in cinema. Marey inspired a generation of artists, first of all the Italian Futurists. One of modern Euro coins depicts the sculpture "Continuous Shapes in the Space" by Futurist Giacomo Balla. The painting "The Hand of the Violinist," shown in Figure 27, also by Balla, gives the feeling of motion and gestures, even if the number of superposed images is discrete.

The second concept we may refer to is the L-system. It is a mathematical concept first developed by botanist Aristid Lindenmayer, who tried to describe in precise terms the

growth and development of vegetables. It is a recursion process. There are several wonderful images obtained from mathematical definition of L-systems. They are very similar to real vegetables, as in Figure 28. L-systems are evidently discrete. We can see L-system as the discrete limit of continuous gestures and hypergestures. Let us now analyze the structure of the nymphaea and its musical rendition. The structure of each petal is similar to the others. Here, the main challenge is giving the idea of rotational shape through sound. The entire structure may be projected inside the tridimensional graph of time-loudness-pitch. However, I wanted to give the idea not only of a 'static' shape, but also of the *movement*. It may be the hand moving around the nymphaea, or a virtual photocopy of a petal along a cone having the vertex at the base of the flower. We have similar ideas in solid geometry when we describe a cone, or a cylinder, as a *rotational* solid. Here, the gesture would be such a rotational movement.

Figure 27

Let us first consider a simplification of the nymphaea: four big external petals, and four smaller internal petals, let them be first and second row, respectively. We apply the same melody to each big petal, and the another to each small petal. When we 'stay' in a big petal, we hear the first melody played by for example horns. When we move toward another big petal, we start hearing the little petal in between, in voice, for example. The closer we are to the little petal, the louder we hear its melody, and the softer we hear the first melody played for example by horns. The closer we are to another big petal, the louder we hear its melody, and the softer we hear the vocal melody. Changes in loudness help the feeling of movement and directionality.

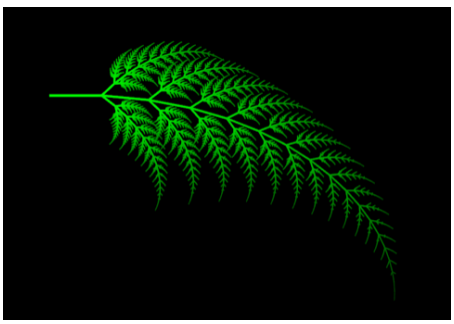

Figure 28

To increase the ‘realism’ of such an effect, I also borrowed from physical acoustics the concept of pitch change due to the motion of the sound source, known as the Doppler effect. It is a common phenomenon to hear higher pitch when the sound source is approaching us, and to hear lower pitch when it is moving away. It happens with ambulances, for example. In the piece, of course the petals are not moving, but we can suppose walk around them. However, let us suppose the opposite, as in the case of people traveling on trains, who see the landscape moving around them as the result of their relative motion. When we move away from the first petal, we hear its melody played again but lower in pitch, and lower in loudness until it disappears. The opposite happens with the melody sung by the voice: the closer we are, the higher in pitch and in loudness the singer sings. This simple mechanisms leads to a score corresponding to the gestural representation of the nymphaea. For simplicity, I used an upper and lower contour for each petal of the first row, and only an upper contour for each petal of the second row. See Figure 29.

How does the subject change according to the shape of this flower? The Doppler-like effect is kept, and applied to the instruments performing the countersubject. The subject (in its rhythmically simplified version) is also… subject to this mechanism, and it is also shaped with notes of the second row’s nymphaea melody.

There is another example of Nymphaea in music, a sonification of a Monet’s painting. Russian Kaia Saariaho (Tsaregradskaya 2016) translated the direction/pressure of the painter’s brush into bowing indications and notes.

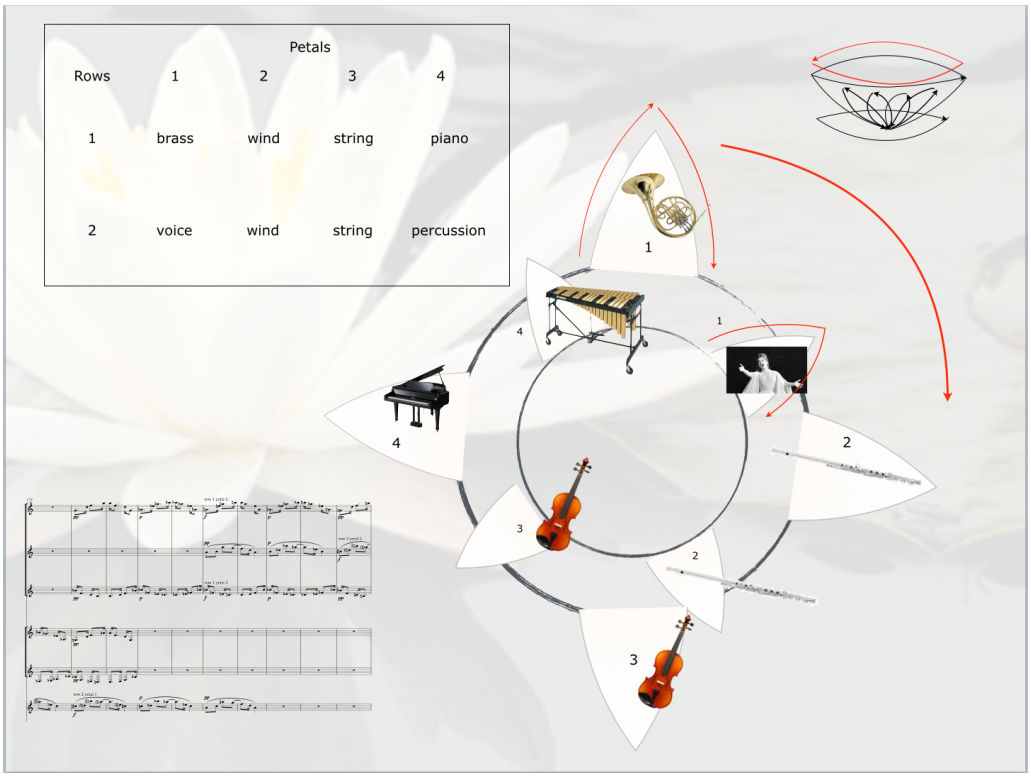

Figure 29

The head of the subject shaped as nymphaea (mm. 214-222), winds, horns and voice, is shown in Figure 30.

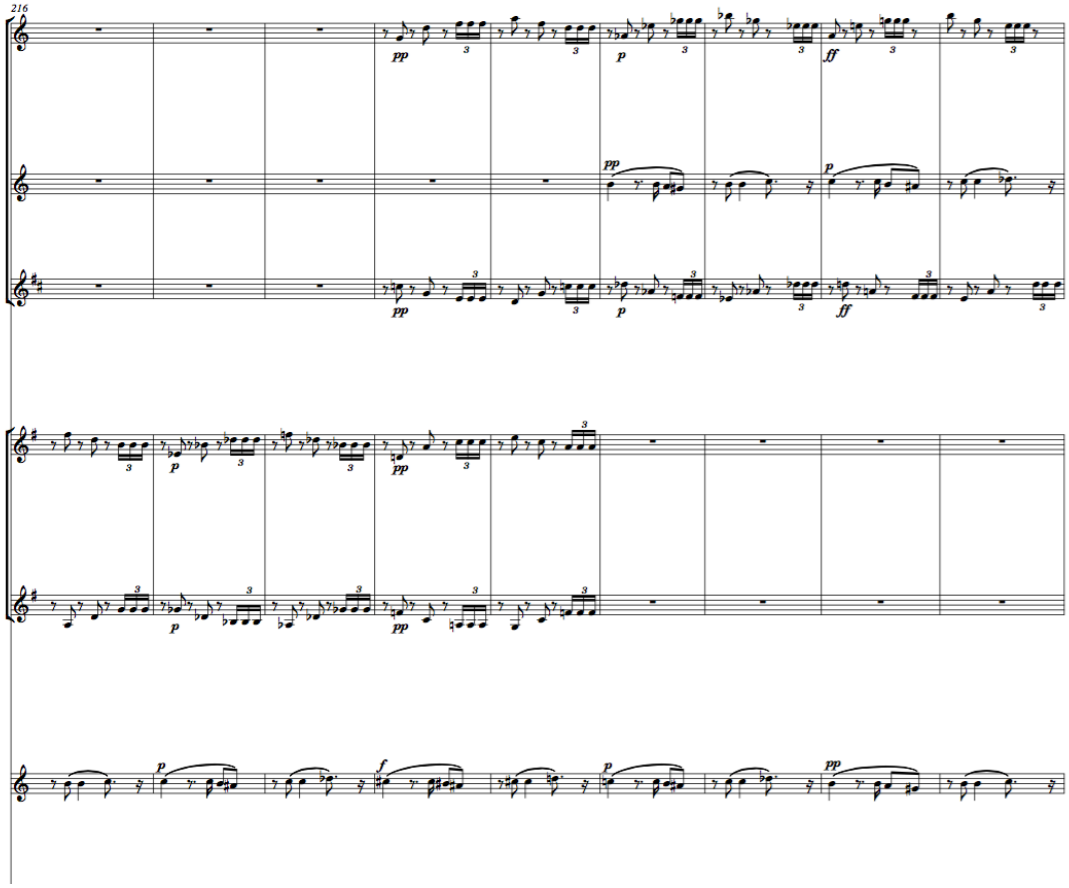

Figure 30: Flute, Clarinet, Bassoon, Horns in F,
Voice.

3. Conclusions

In this work, the starting point was twofold: the mathematical theory of musical gestures, and the mapping from tridimensional images to music. These two scientific approaches to music are both present in my composition for orchestra in two movements, *Genesis of Music from Gestures*, comprised of a fantasia and a fugue.

The interest in a *fantasia* and *fugue* owes to their antithetical structure, respectively, very free and very strict. However, some of the constraints in a classical form can be partially released in favor of a more modern aesthetic—for example, dissonance—while keeping the expressive strength and the unity provided by the subject and its repetitions, variations, and derivations. Writing a fugue today is a way to rediscover the heritage of the past under the light of new thinking and new scientific and creative tools.

One of the challenges here was the use of mathematically-inspired structures to make something of artistically meaningful. Another challenge was represented by retaining my personal style in a mathematically-inspired music.

I tried to respect precise formal concepts. I found that theoretical thinking is applicable not only to analysis, but also to creativity. Conversely, art can stimulate rational thinking. Future compositions may involve the use of musical software such as Open Music[11] and Rubato[12] to build sections of a piece, without renouncing personal artistic control.

New perspectives on art-science can thus be opened, not only for composers, but also performers. Thinking about gestures helps provide performers with new perspectives on standard repertoire, as well as to approach new works. Scientists can also take advantage from such studies, trying to extend the formalism of physics and mathematics to other fields such as art.

[11] http://repmus.ircam.fr/openmusic/home

[12] http://www.rubato.org

Figure 31: “Mathematics and Music,” drawing by Maria Mannone.

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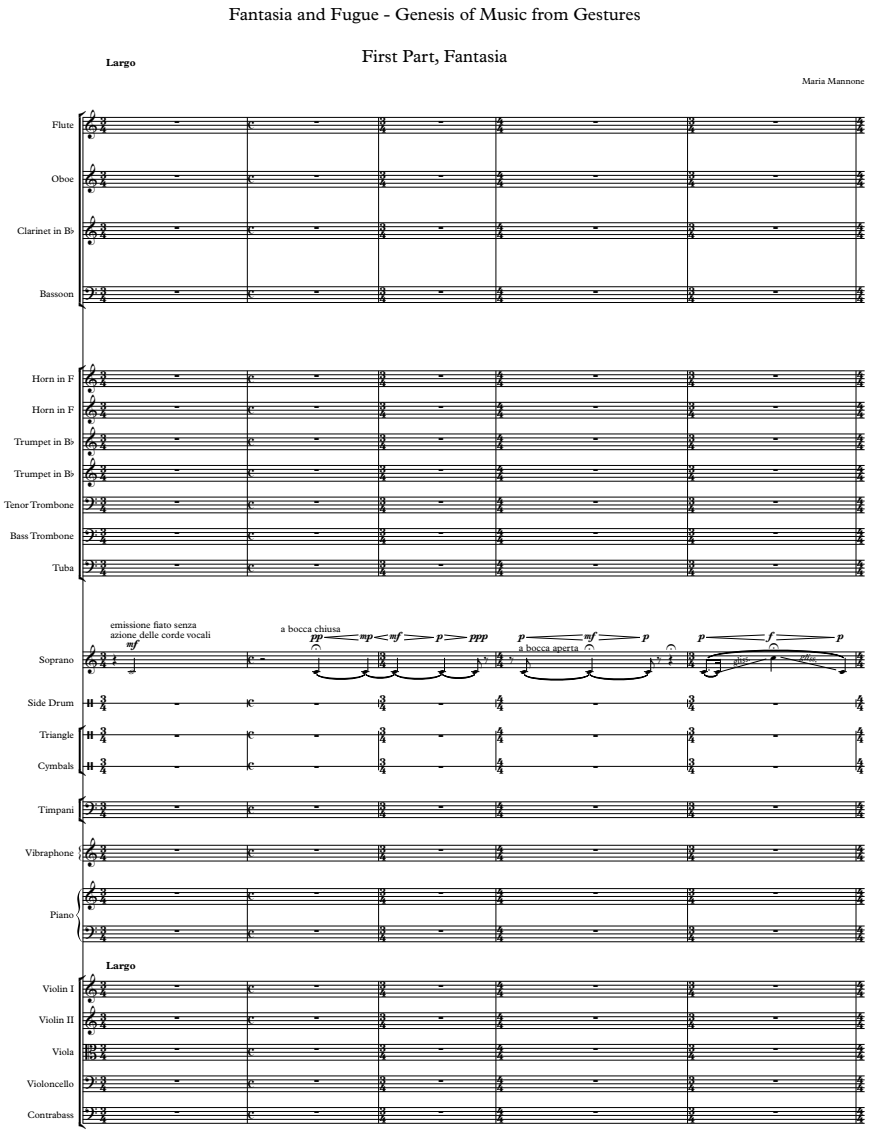
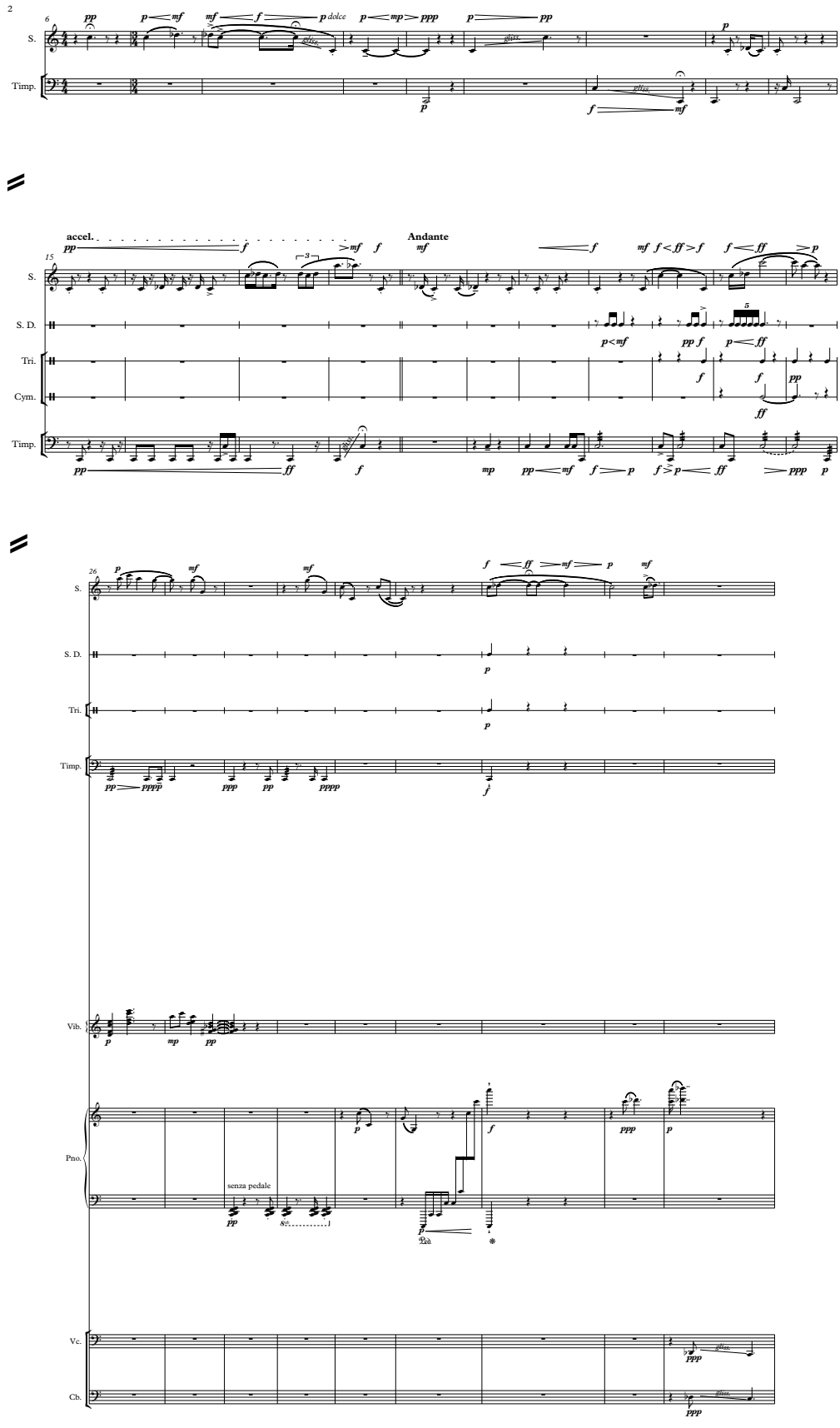
5. Appendix: The Complete Score

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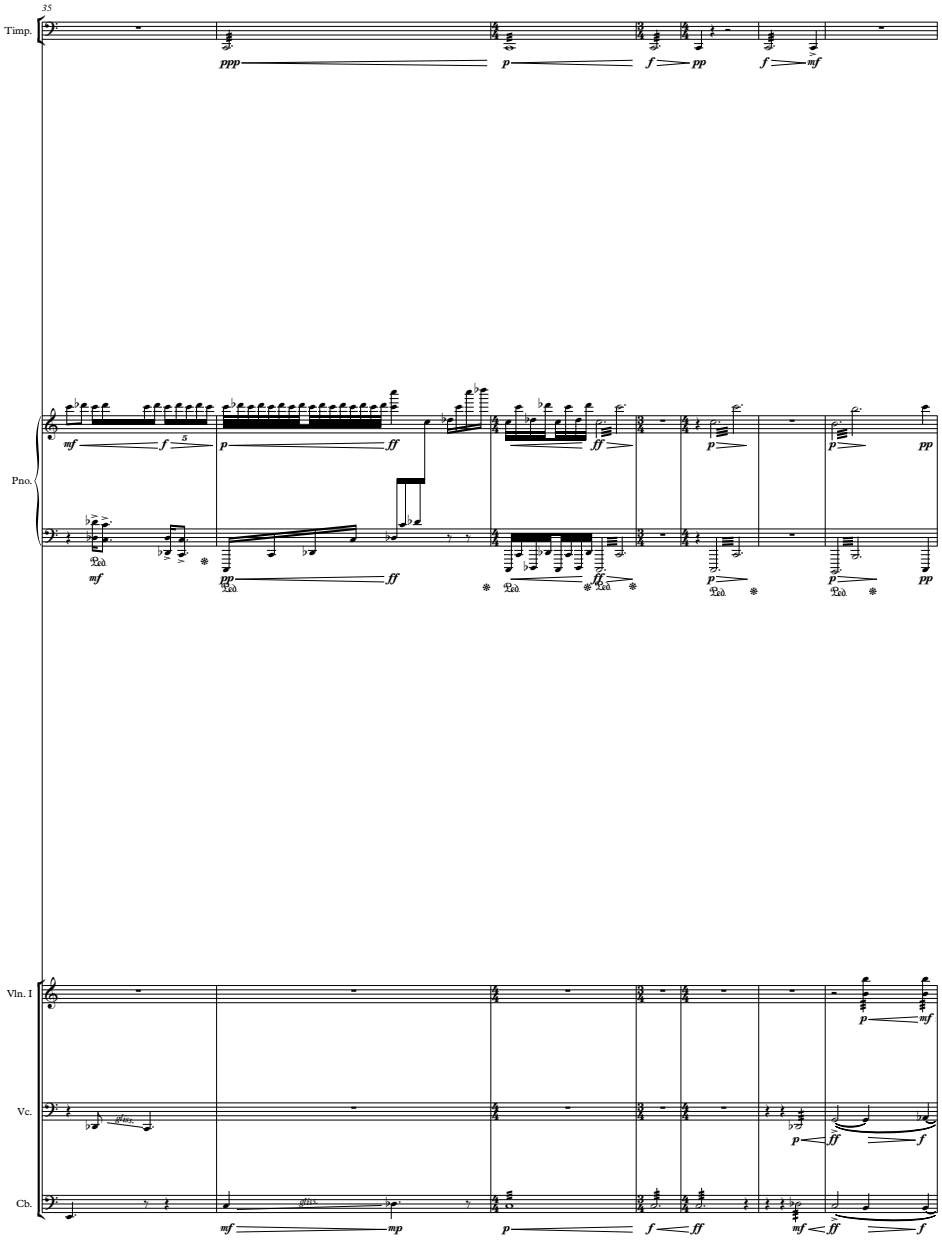
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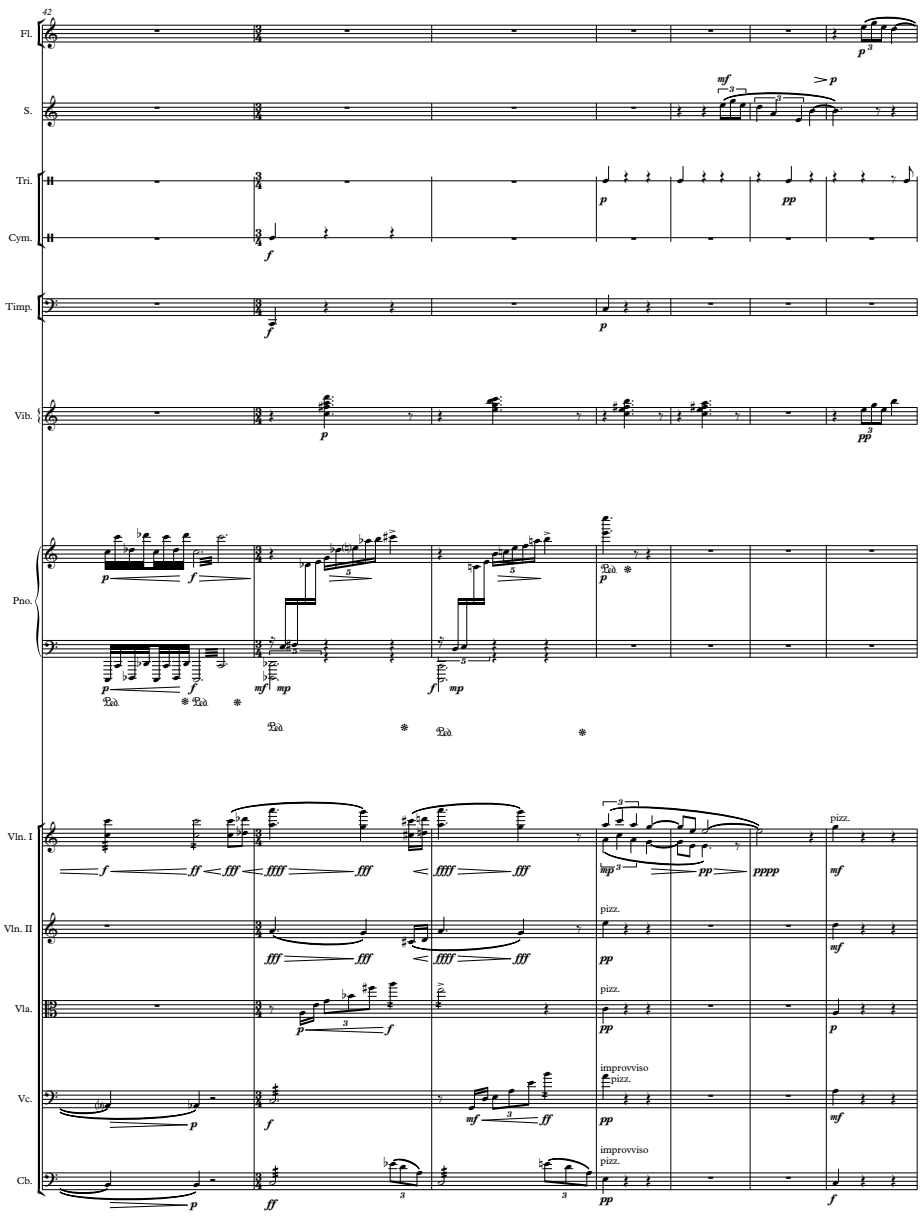
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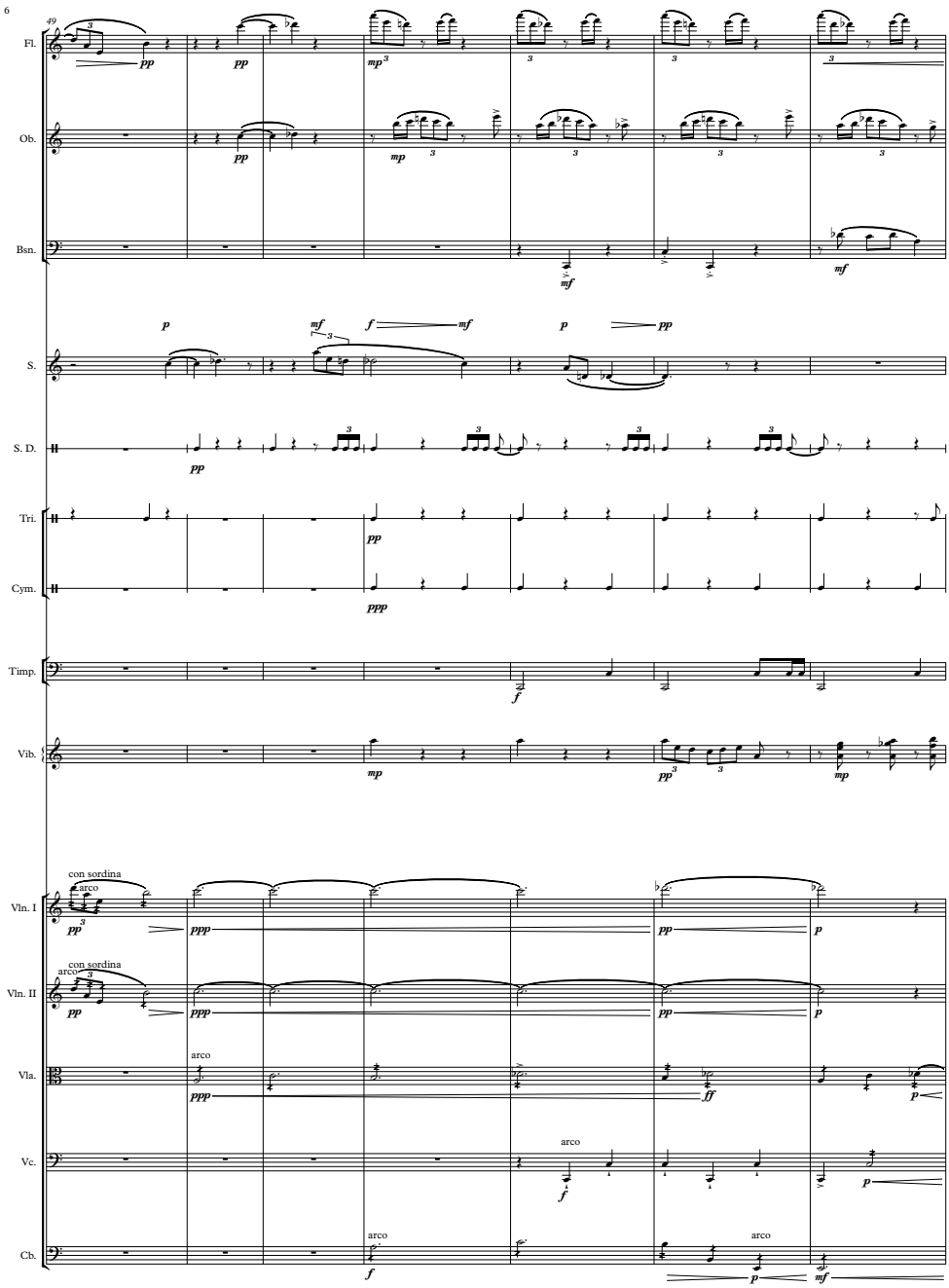
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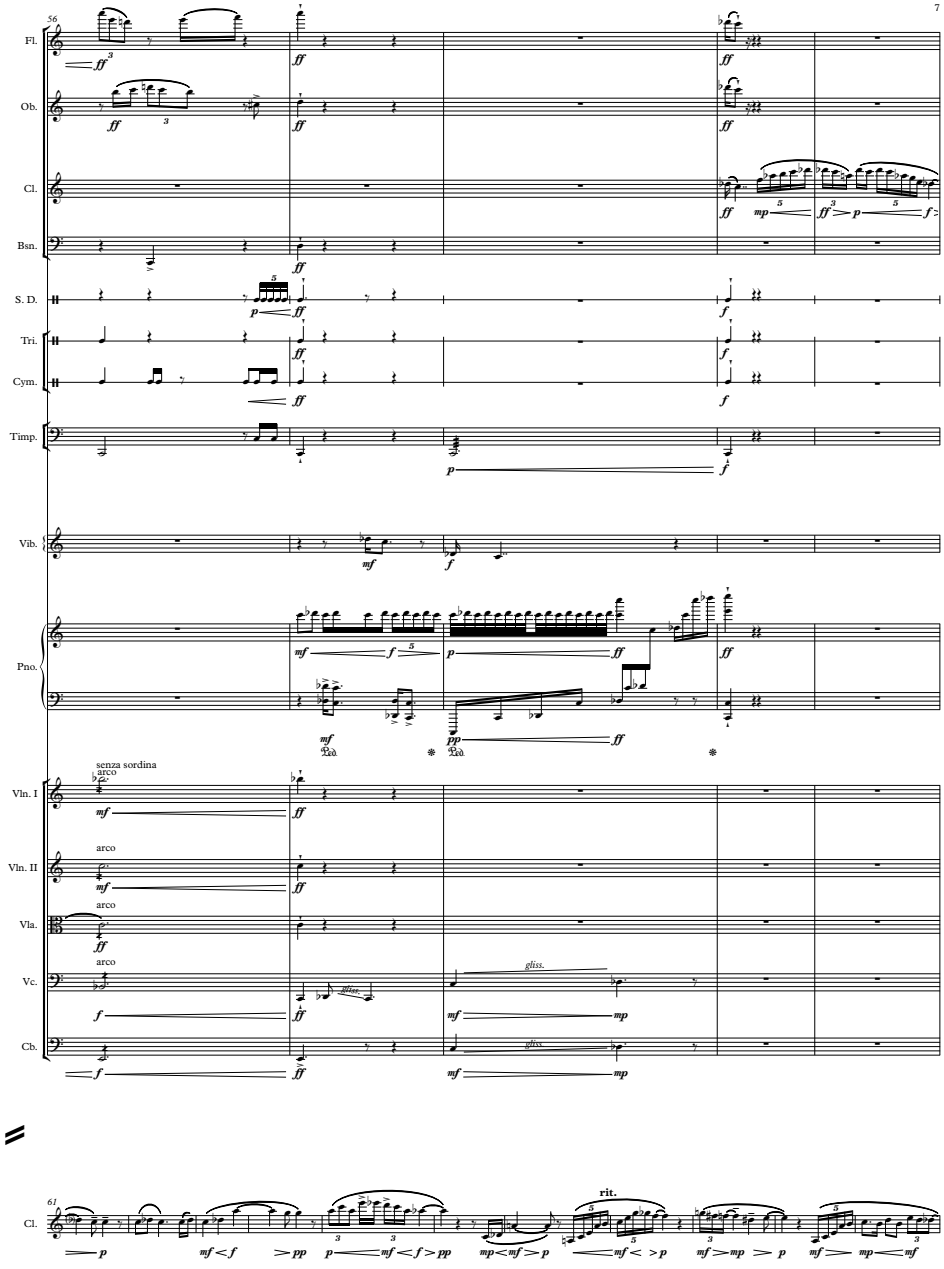
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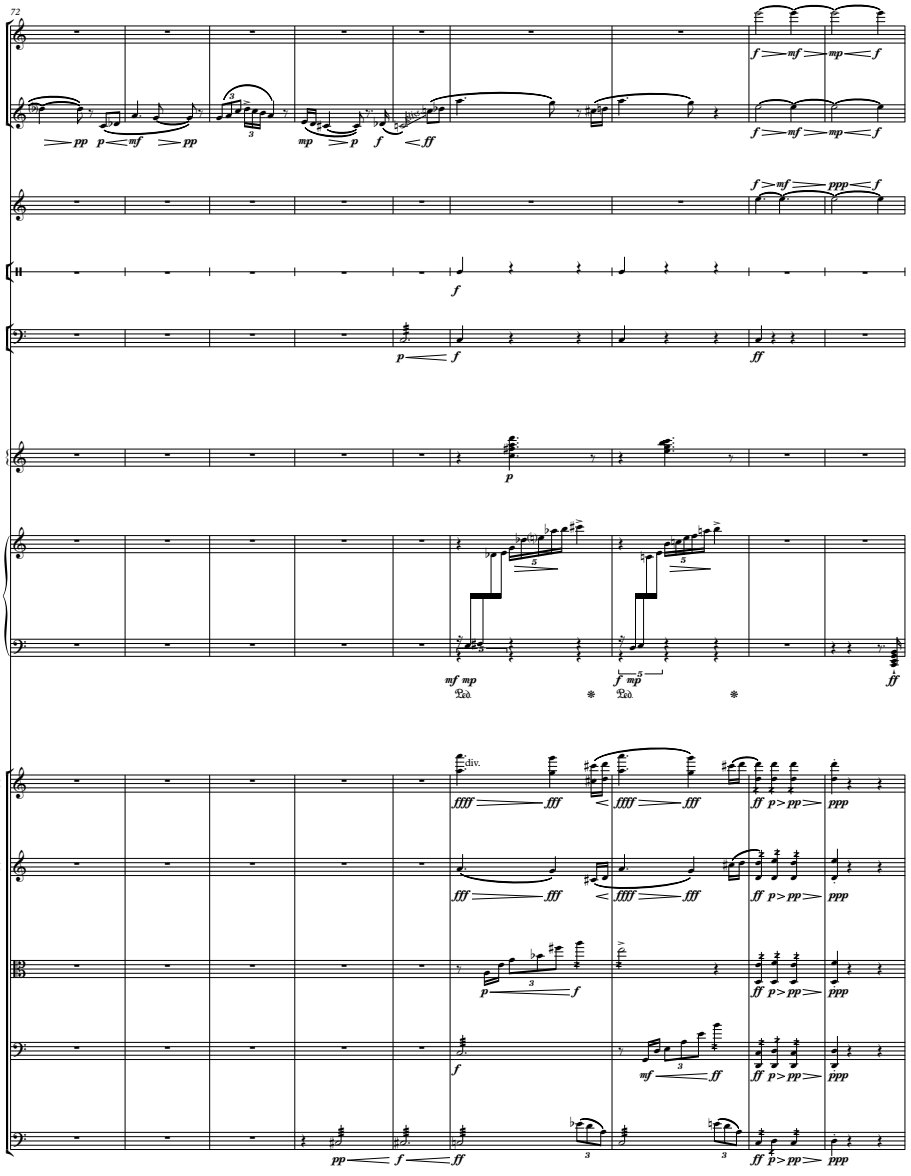
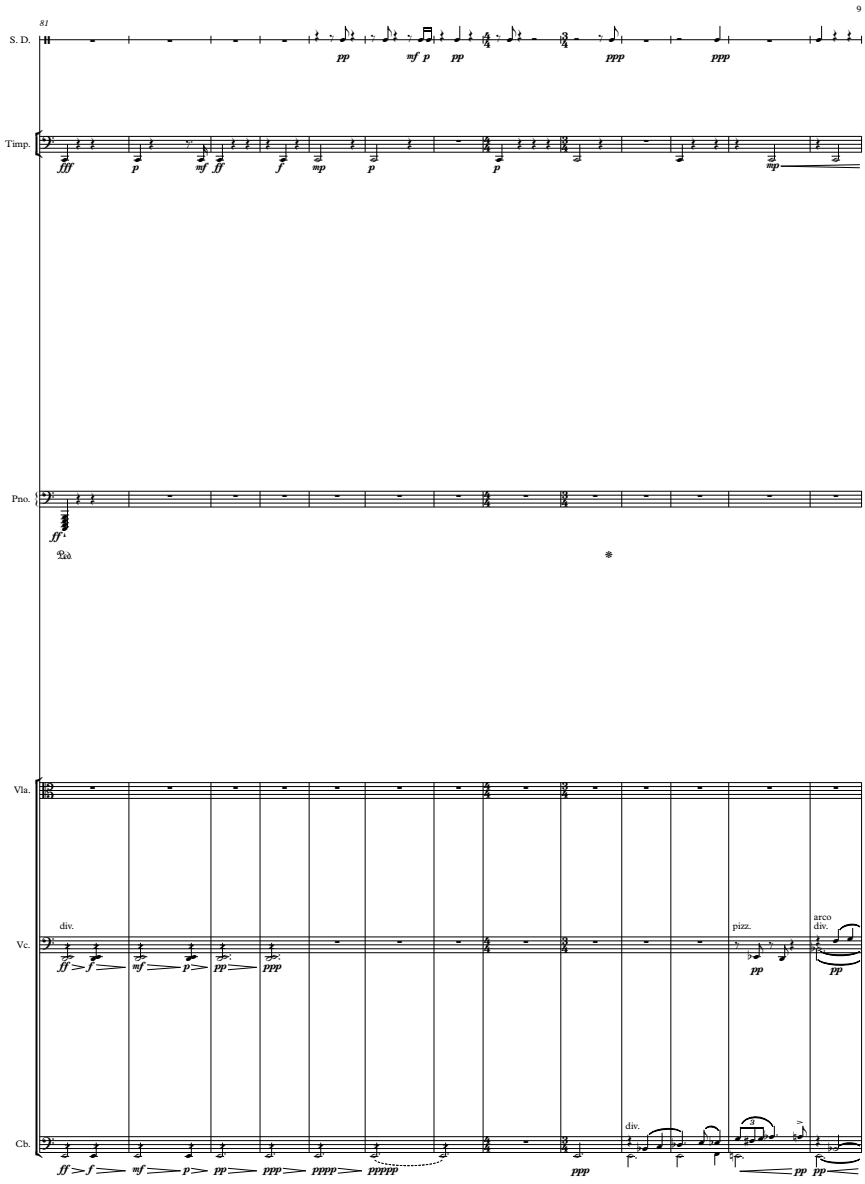
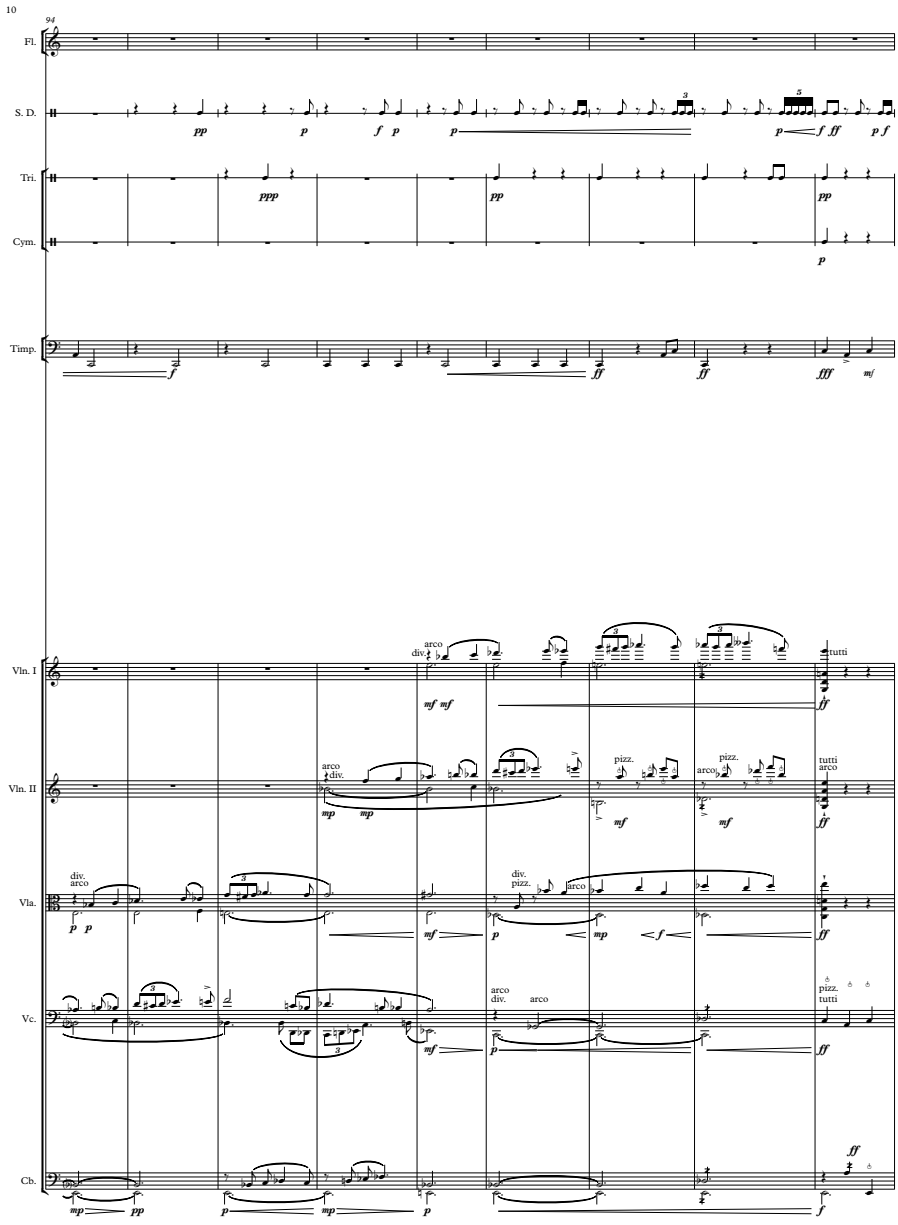
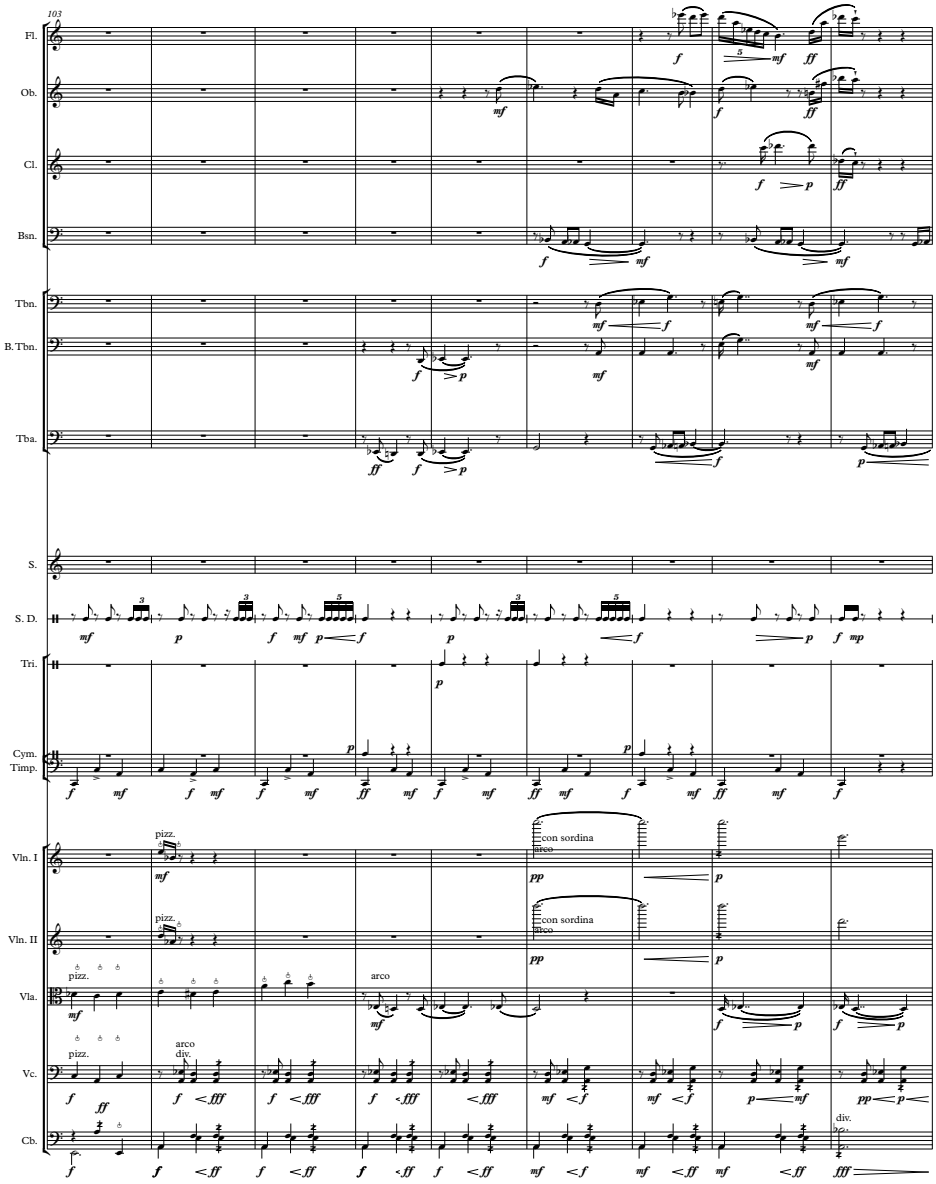
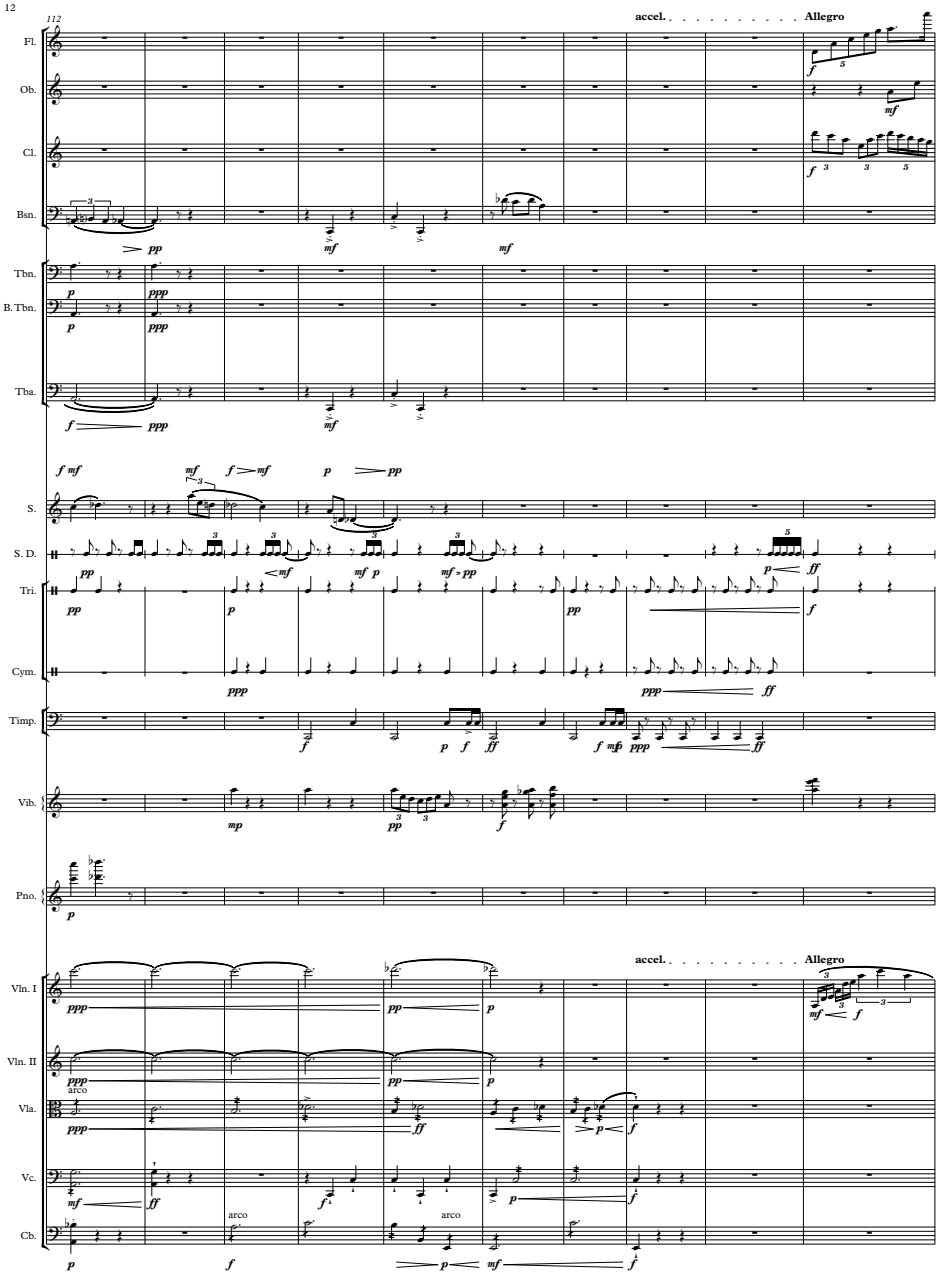
Fl.
Ob.
Cl.
Bsn.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.
senza sordina
arco
arco
arco
gliss.
gliss.
61
Cl.
rit.

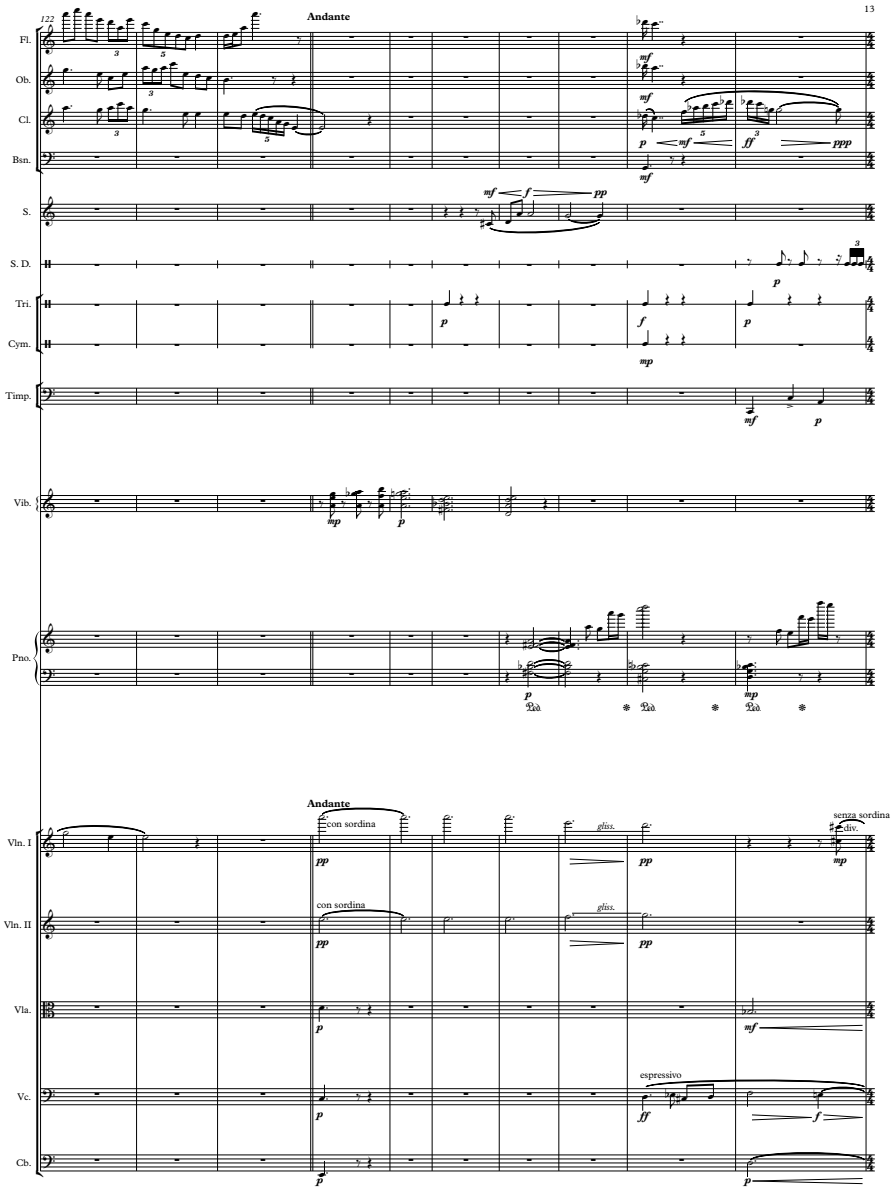

72
Fl.
Cl.
S.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.
div.

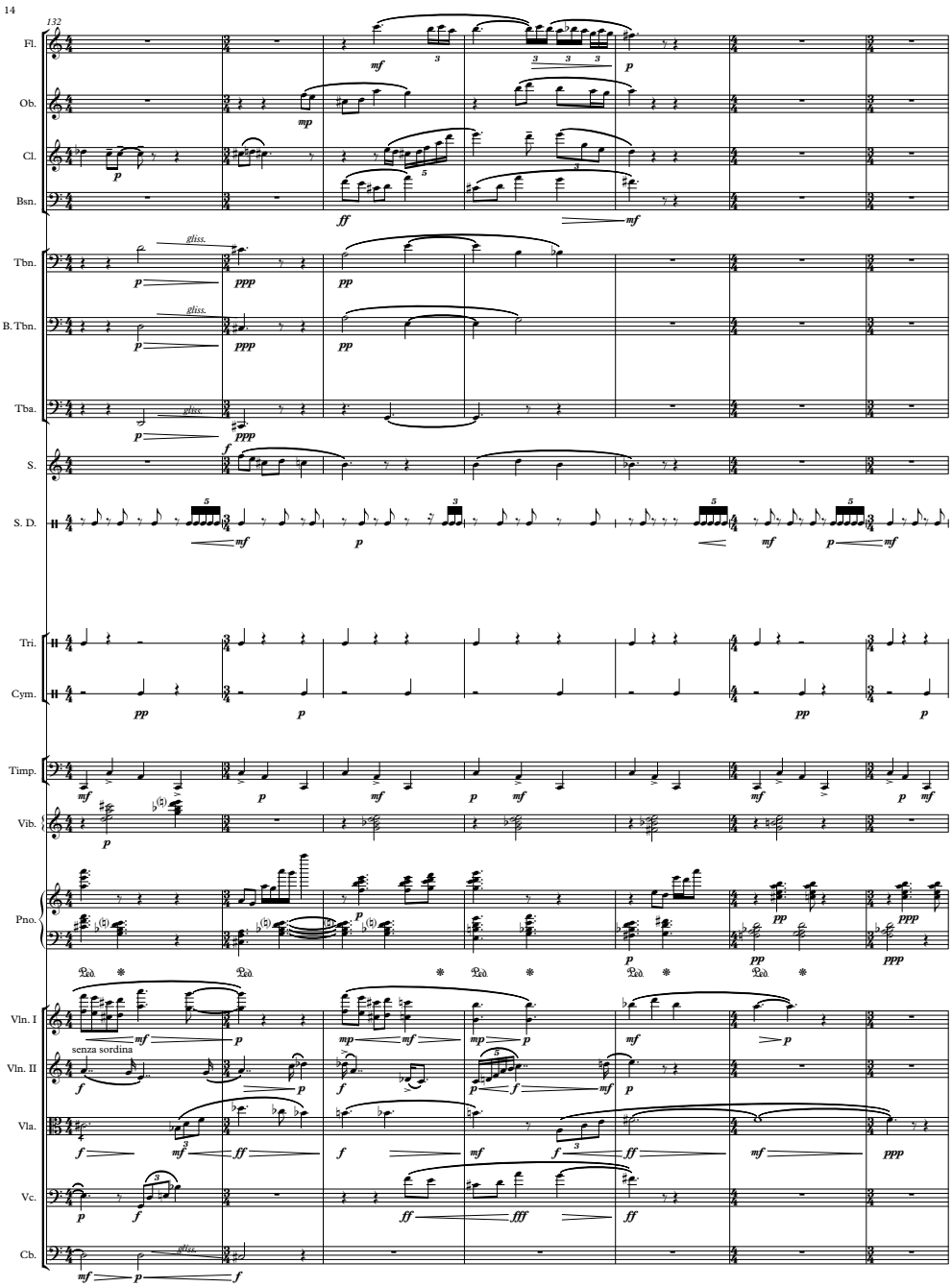

81
9
S. D.
Timp.
Pno.
Vla.
Vc.
Cb.
div.
pizz.
arco
div.

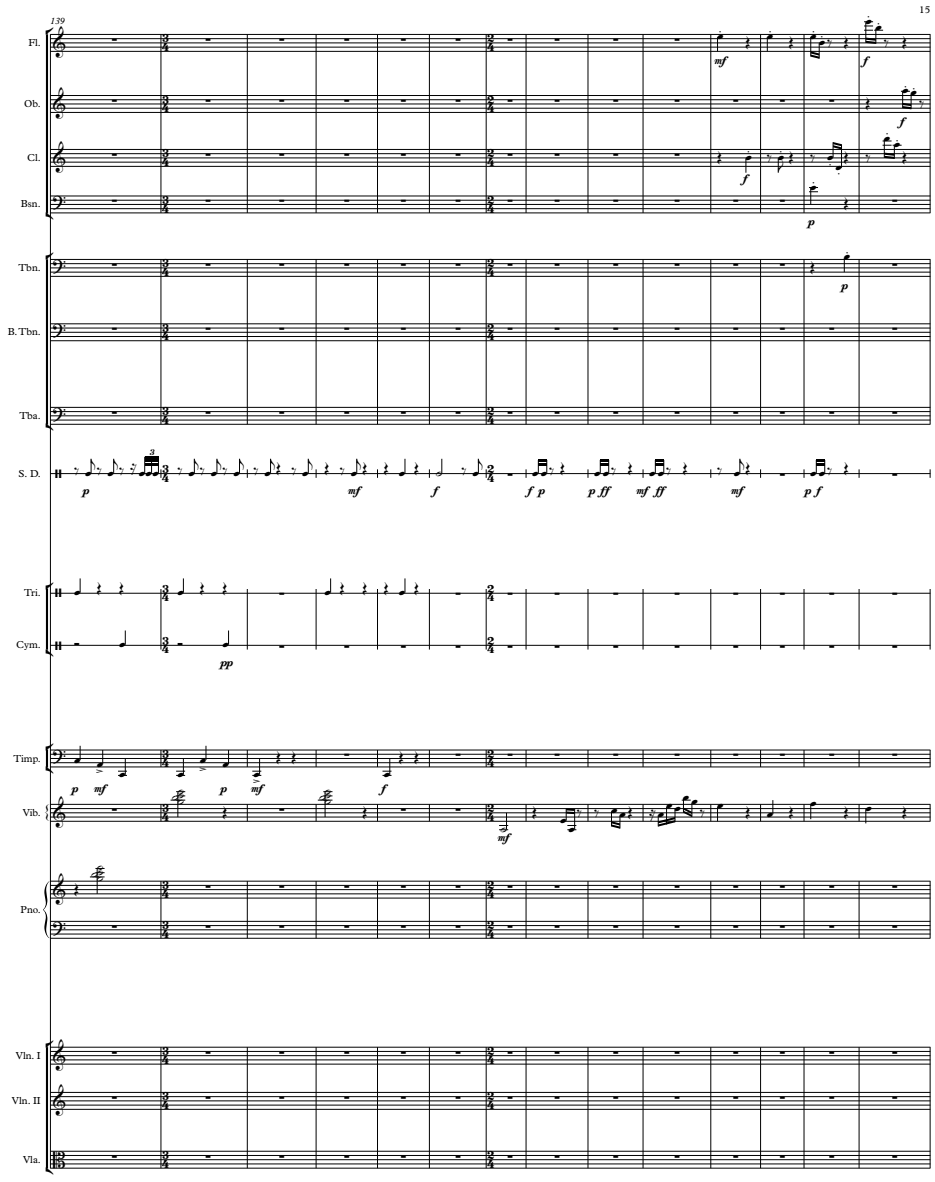

10
94
Fl.
S. D.
Tri.
Cym.
Timp.
Vln. I
Vln. II
Vla.
Vc.
Cb.
arco
div.
tutti
pizz.
arco
div.
pizz.
tutti

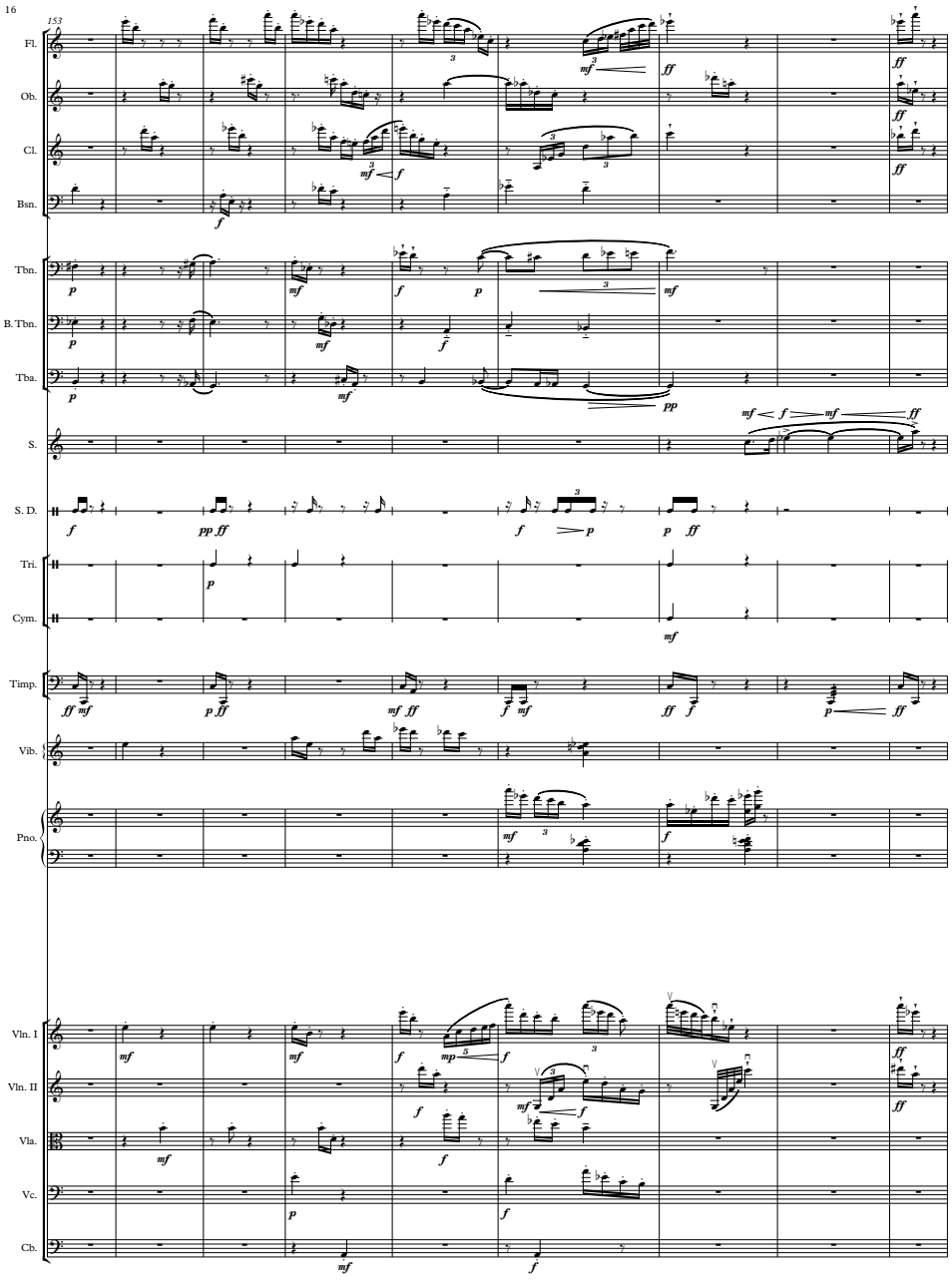

103
Fl.
Ob.
Cl.
Bsn.
Tbn.
B.Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Vln. I
Vln. II
Vla.
Vc.
Cb.
pizz.
arco
div.
con sordina
arco

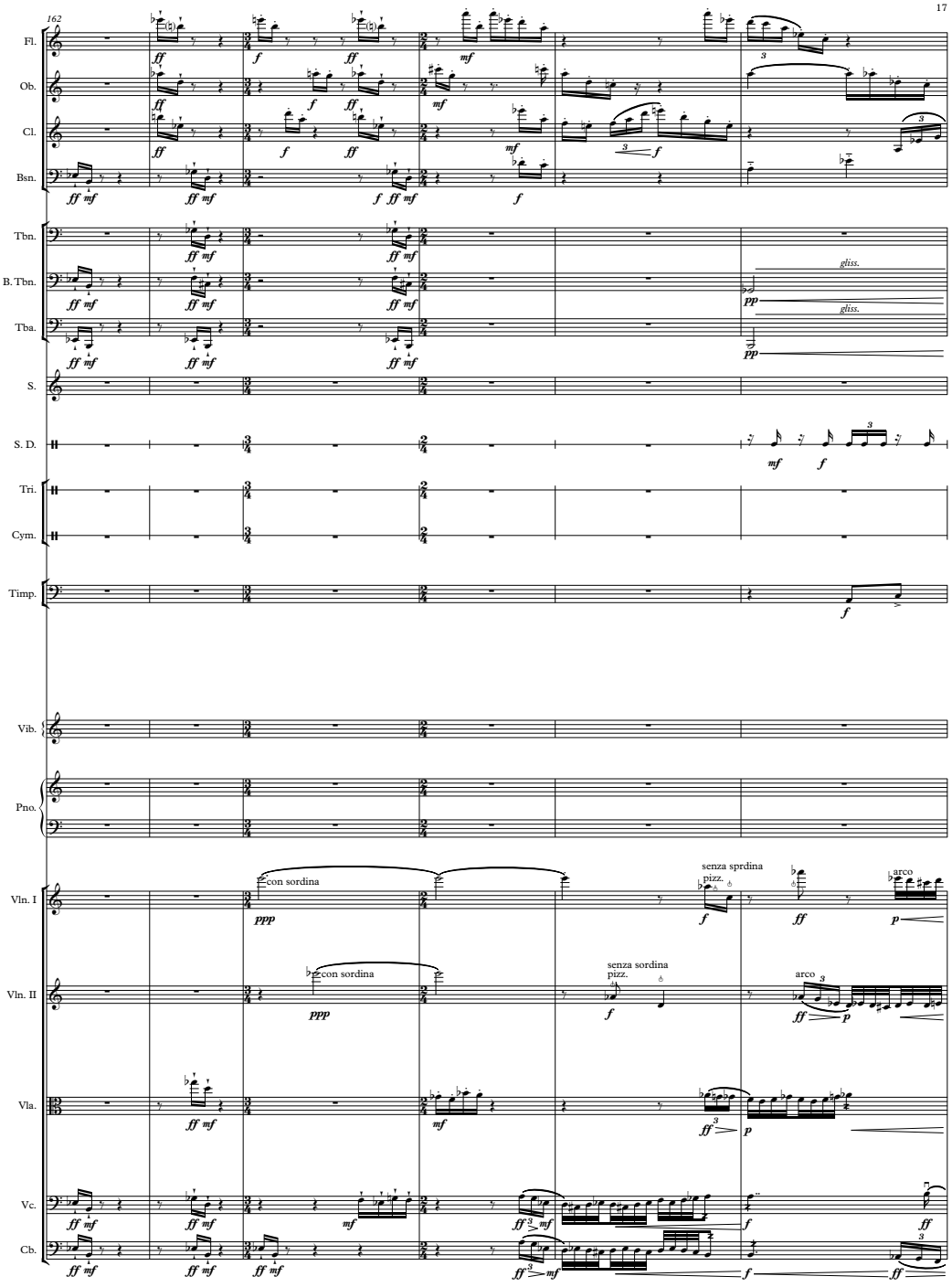

12
112
accel.
Allegro
Fl.
Ob.
Cl.
Bsn.
Tbn.
B. Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
accel.
Allegro
Vln. I
Vln. II
Vla.
Vc.
Cb.
arco
arco

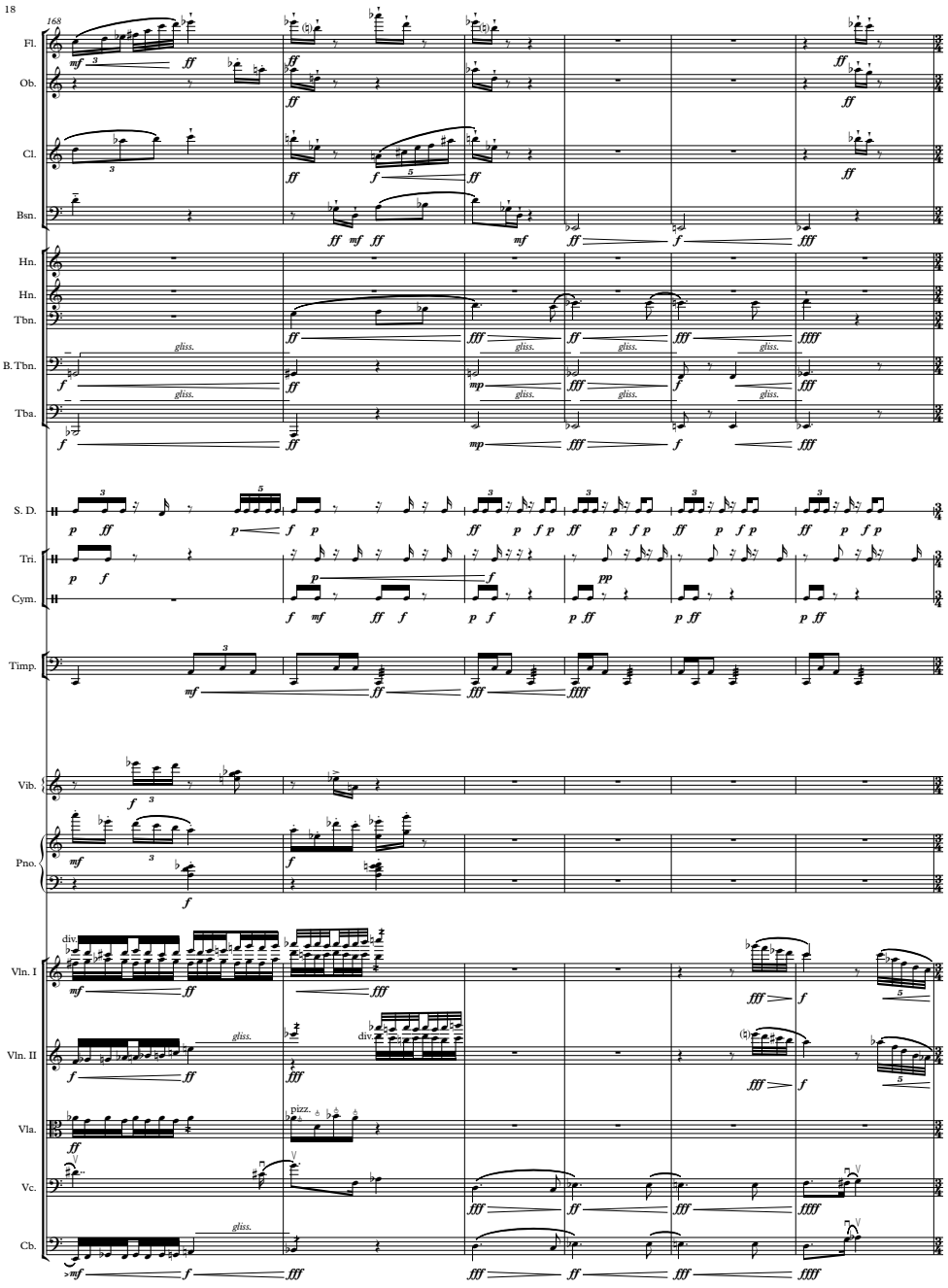

122
Andante
13
Fl.
Ob.
Cl.
Bsn.
S.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Andante
con sordina
senza sordina
div.
Vln. I
Vln. II
Vla.
Vc.
Cb.
gliss.
espressivo

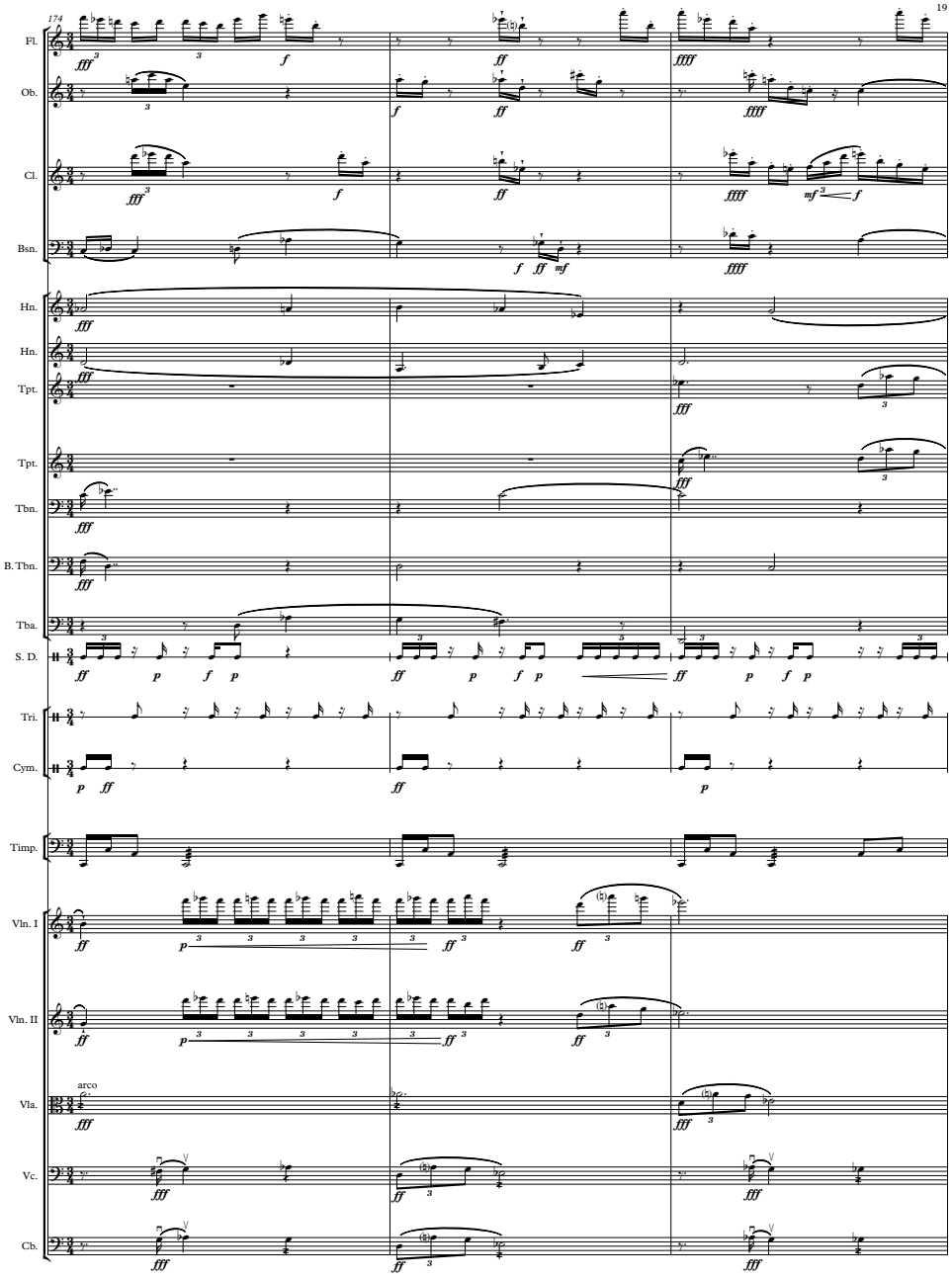

14
132
Fl.
Ob.
Cl.
Bsn.
Tbn.
B. Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.
senza sordina

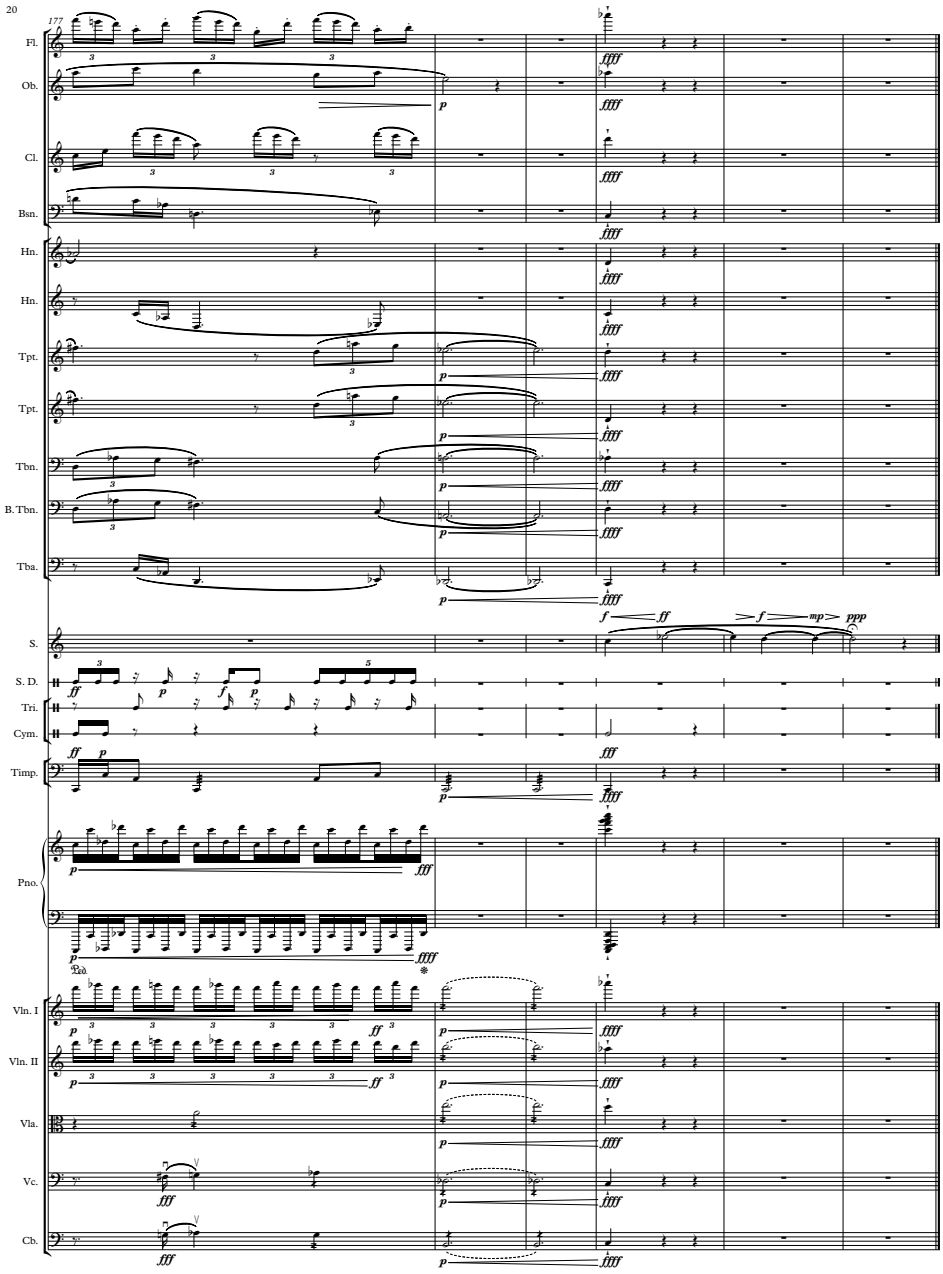

139
15
Fl.
Ob.
Cl.
Bsn.
Tbn.
B. Tbn.
Tba.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.


16
153
Fl.
Ob.
Cl.
Bsn.
Tbn.
B. Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.


162
Fl.
Ob.
Cl.
Bsn.
Tbn.
B. Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.
con sordina
senza sprdina
pizz.
arco
senza sordina
gliss.

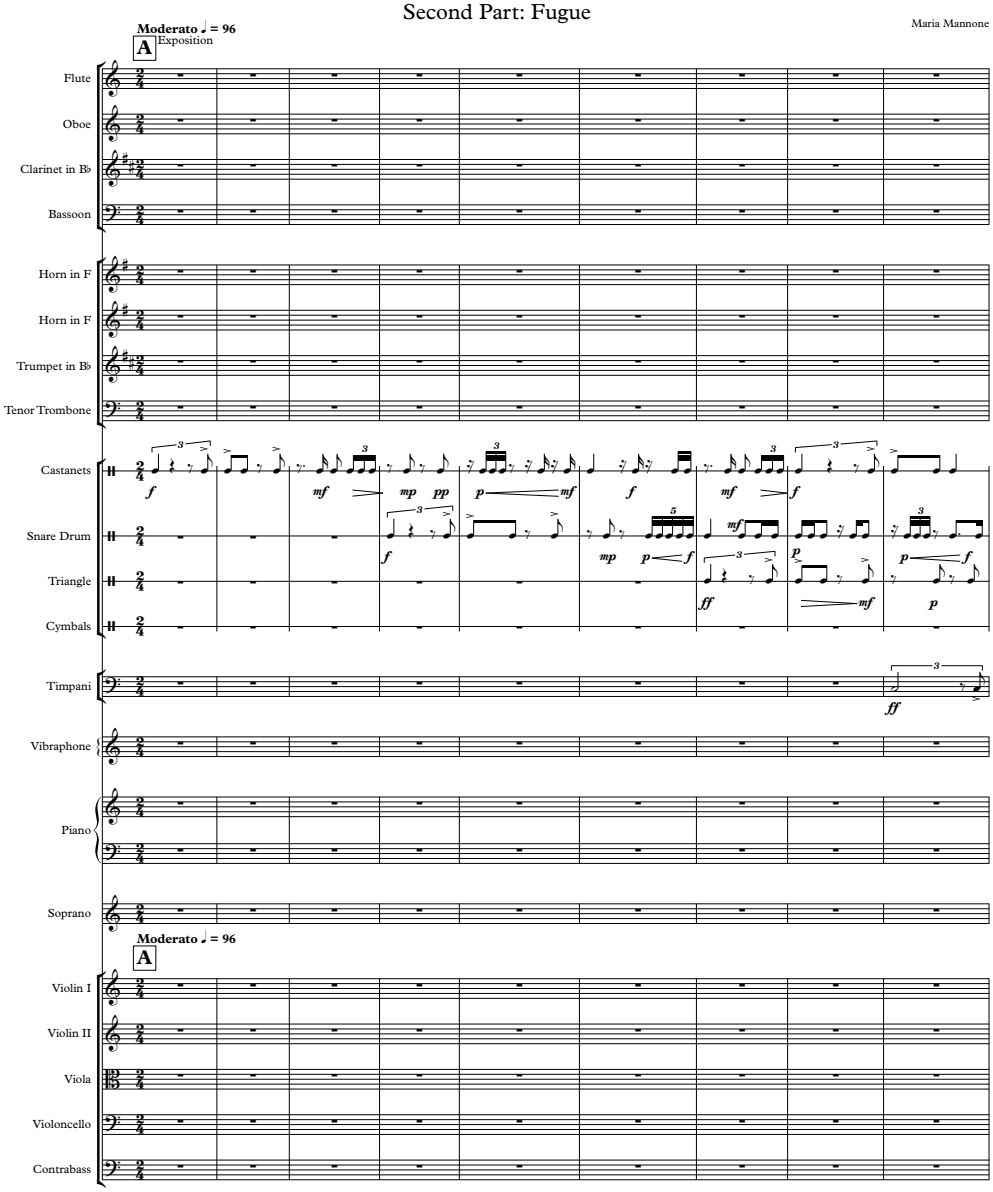

18
168
Fl.
Ob.
Cl.
Bsn.
Hn.
Hn.
Tbn.
B. Tbn.
Tba.
S. D.
Tri.
Cym.
Timp.
Vib.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.
gliss.
div.
pizz.

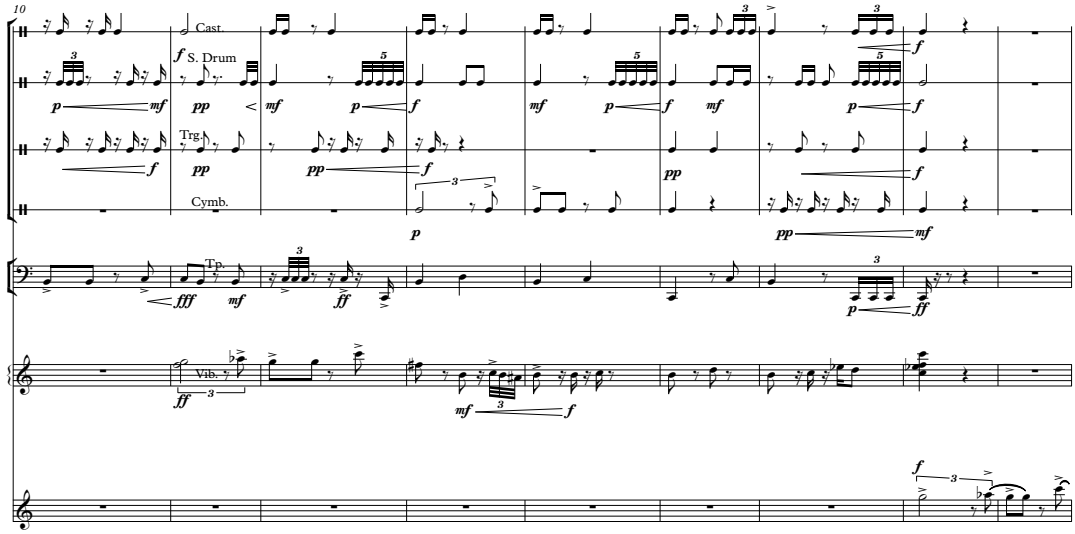

174
19
Fl.
Ob.
Cl.
Bsn.
Hn.
Hn.
Tpt.
Tpt.
Tbn.
B. Tbn.
Tba.
S. D.
Tri.
Cym.
Timp.
Vln. I
Vln. II
Vla.
arco
Vc.
Cb.

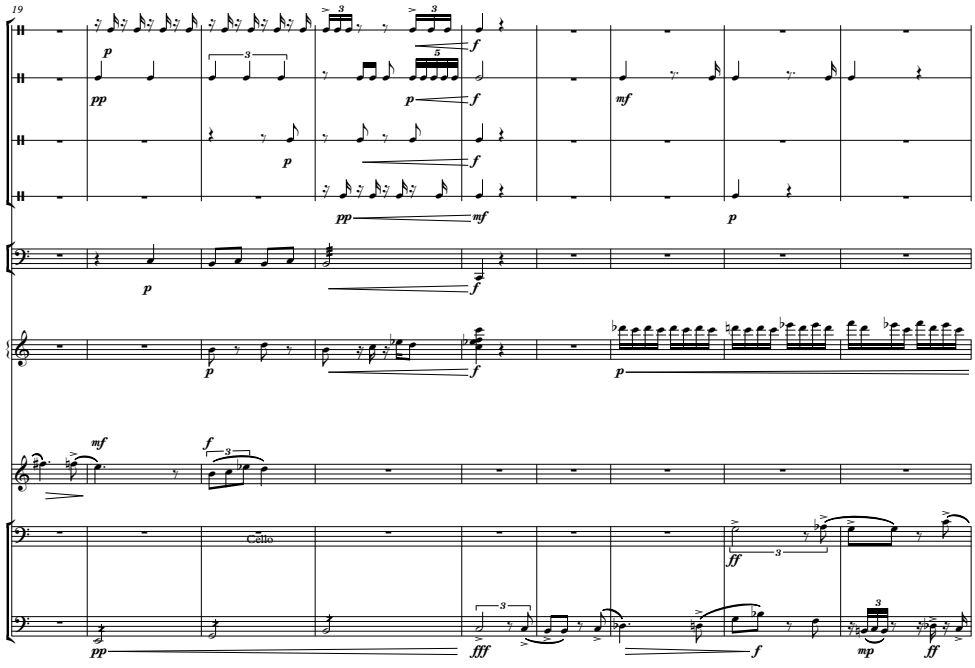

20
177
Fl.
Ob.
Cl.
Bsn.
Hn.
Hn.
Tpt.
Tpt.
Tbn.
B. Tbn.
Tba.
S.
S. D.
Tri.
Cym.
Timp.
Pno.
Vln. I
Vln. II
Vla.
Vc.
Cb.

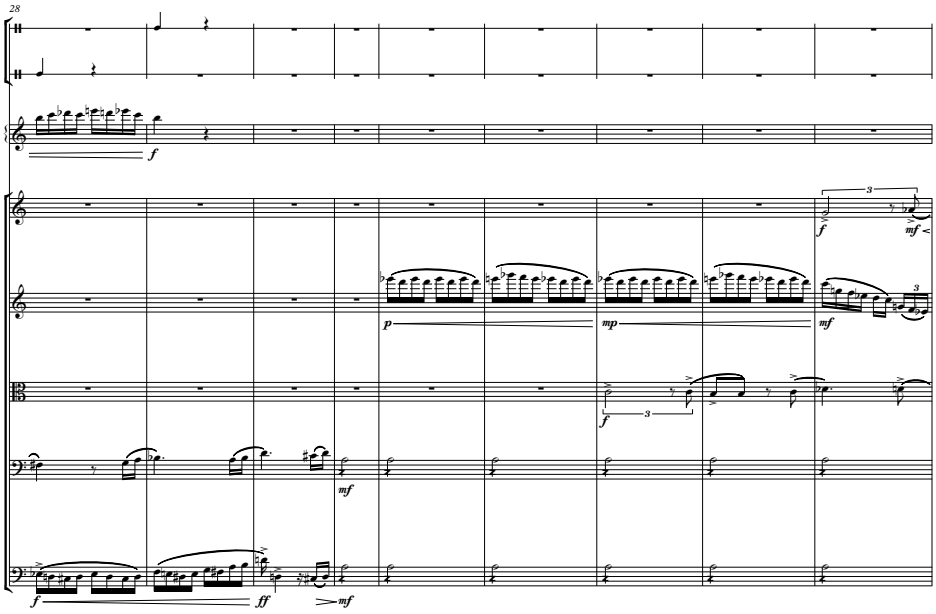
Genesis of Music from Gestures
Second Part: Fugue

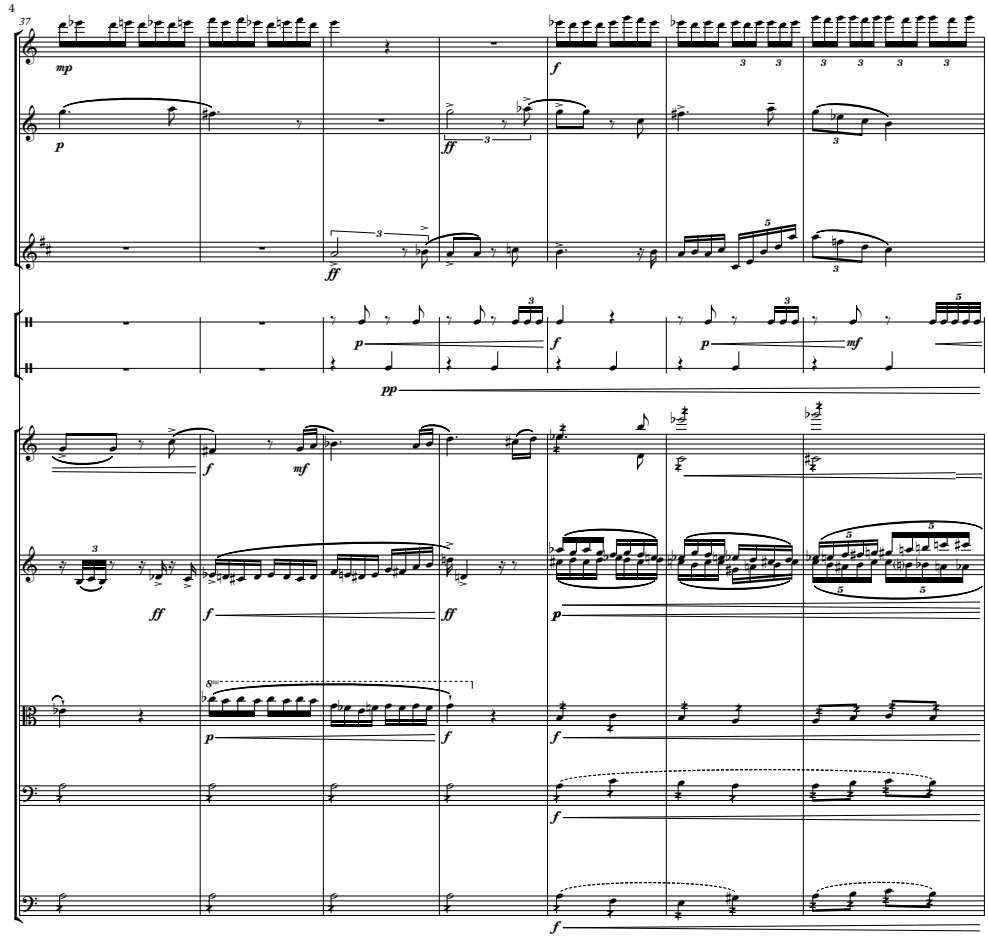
Maria Mannone

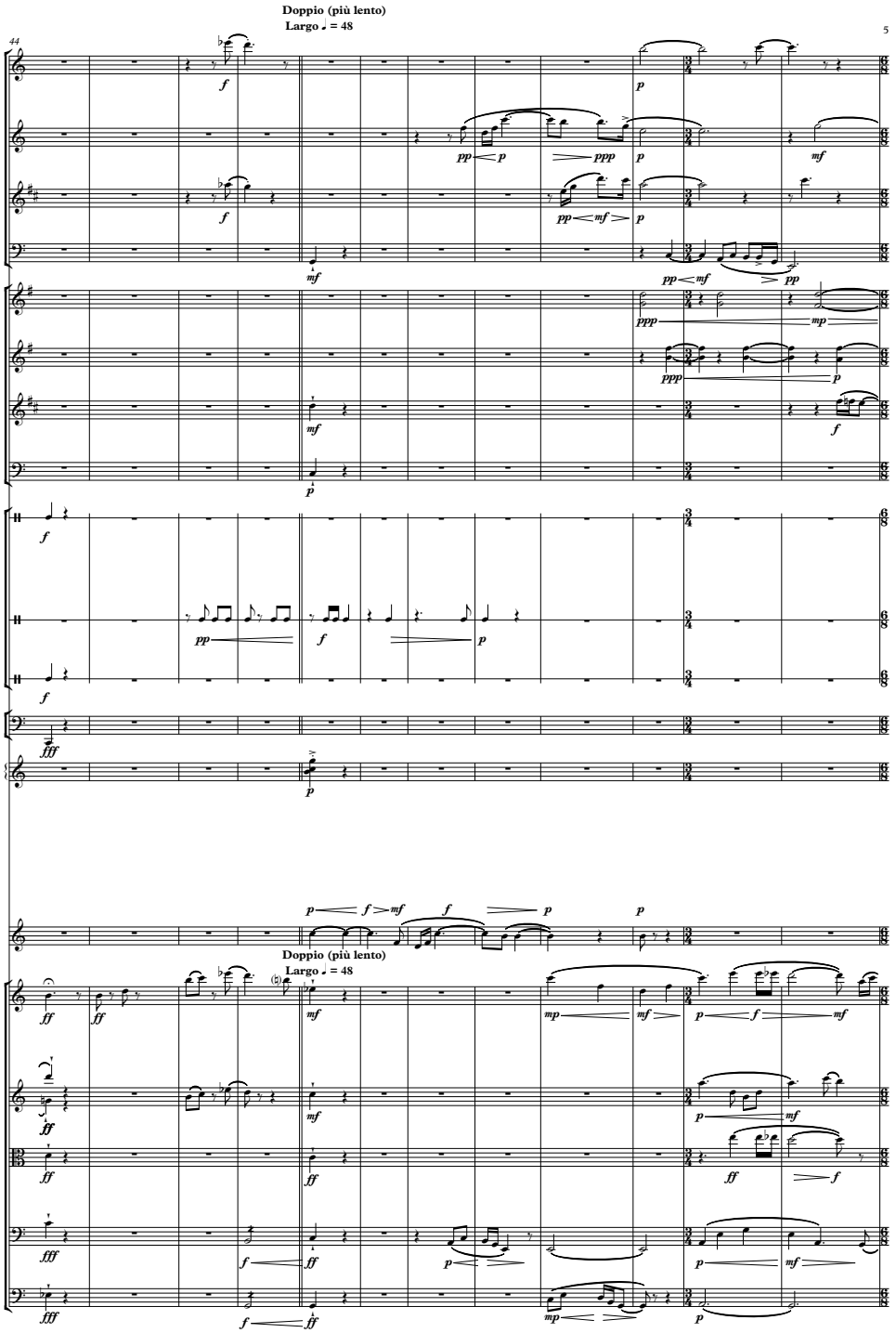


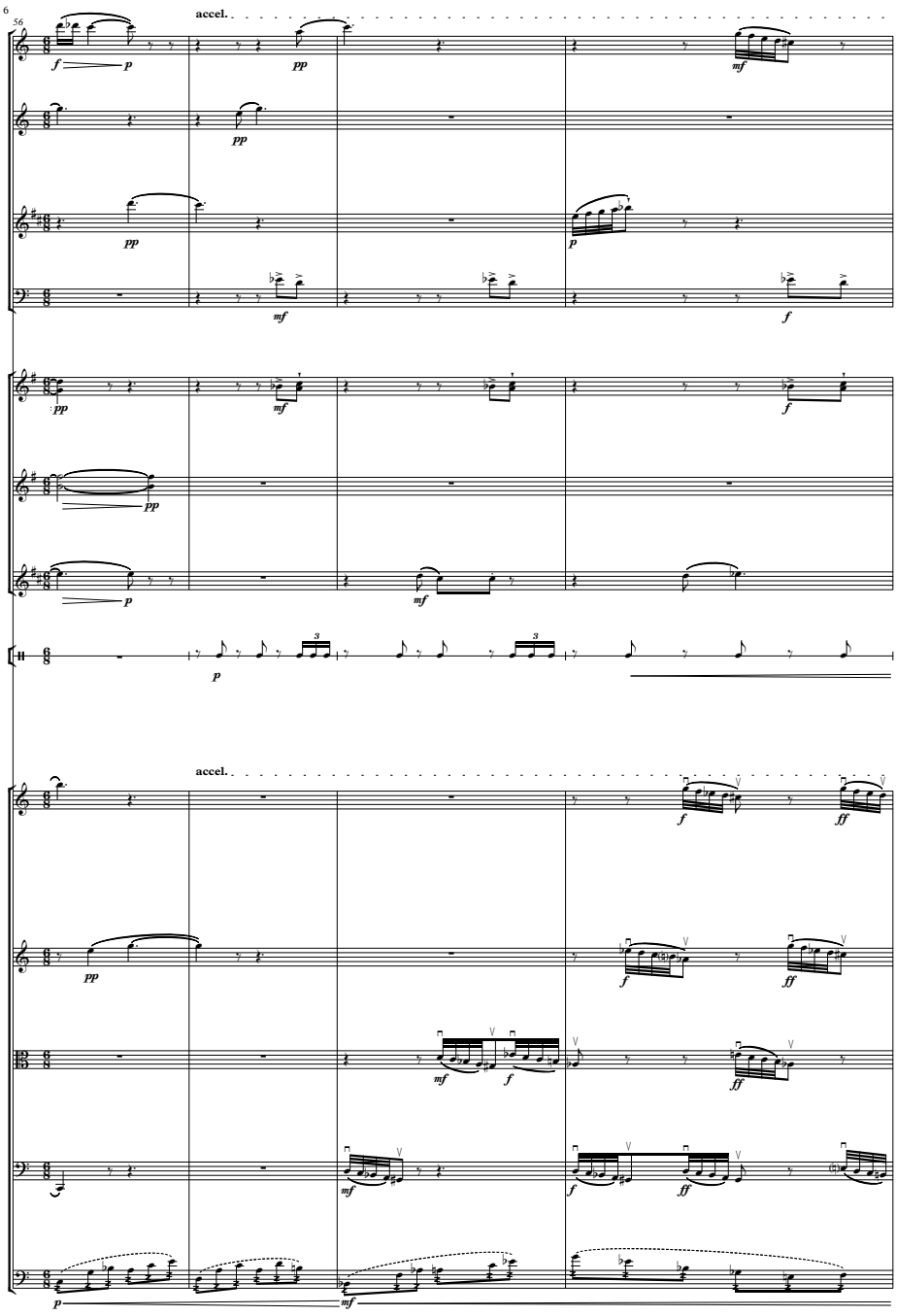

10
Cast.
S. Drum
Trg.
Cymb.
Tp.
Vib.

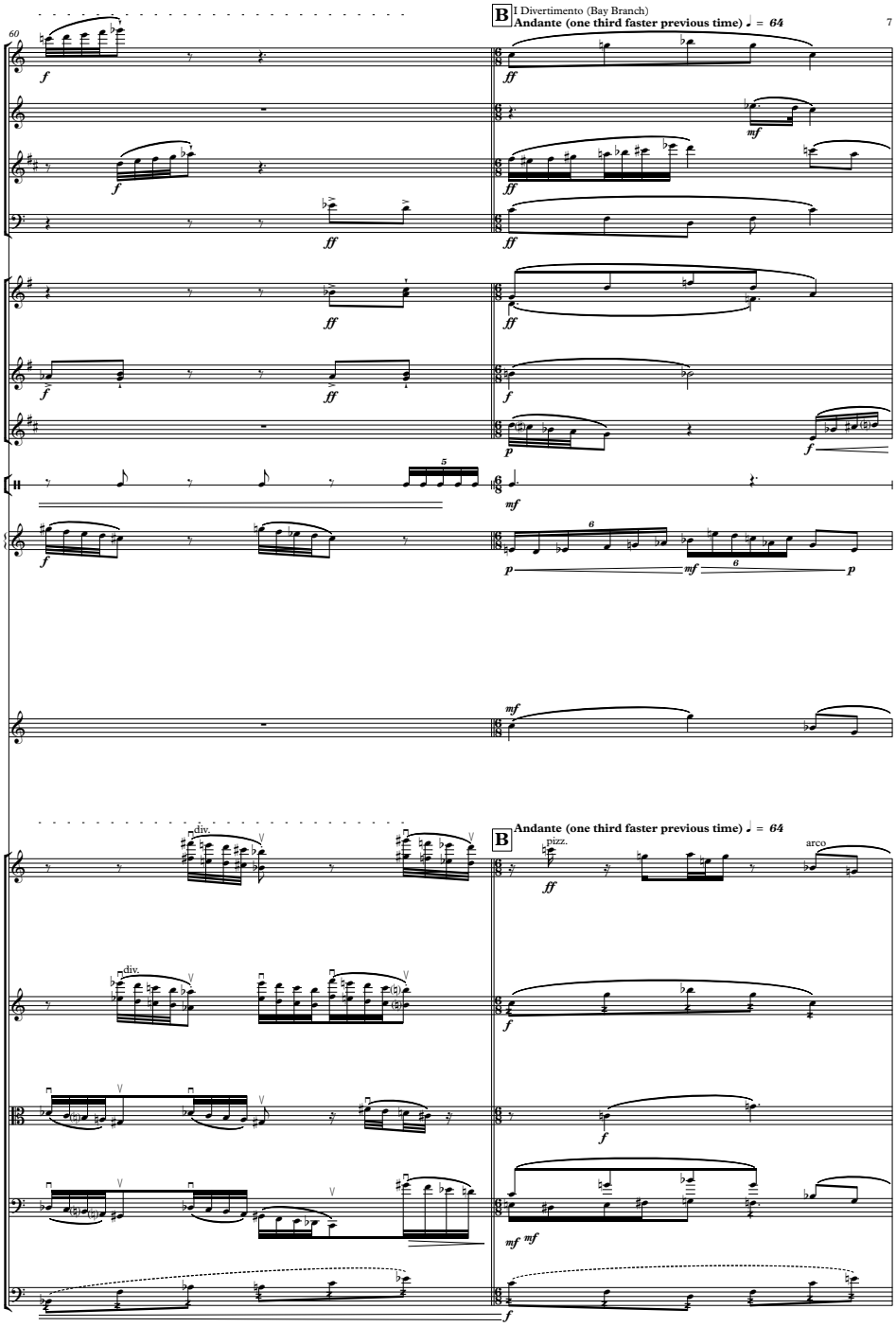

19
Cello

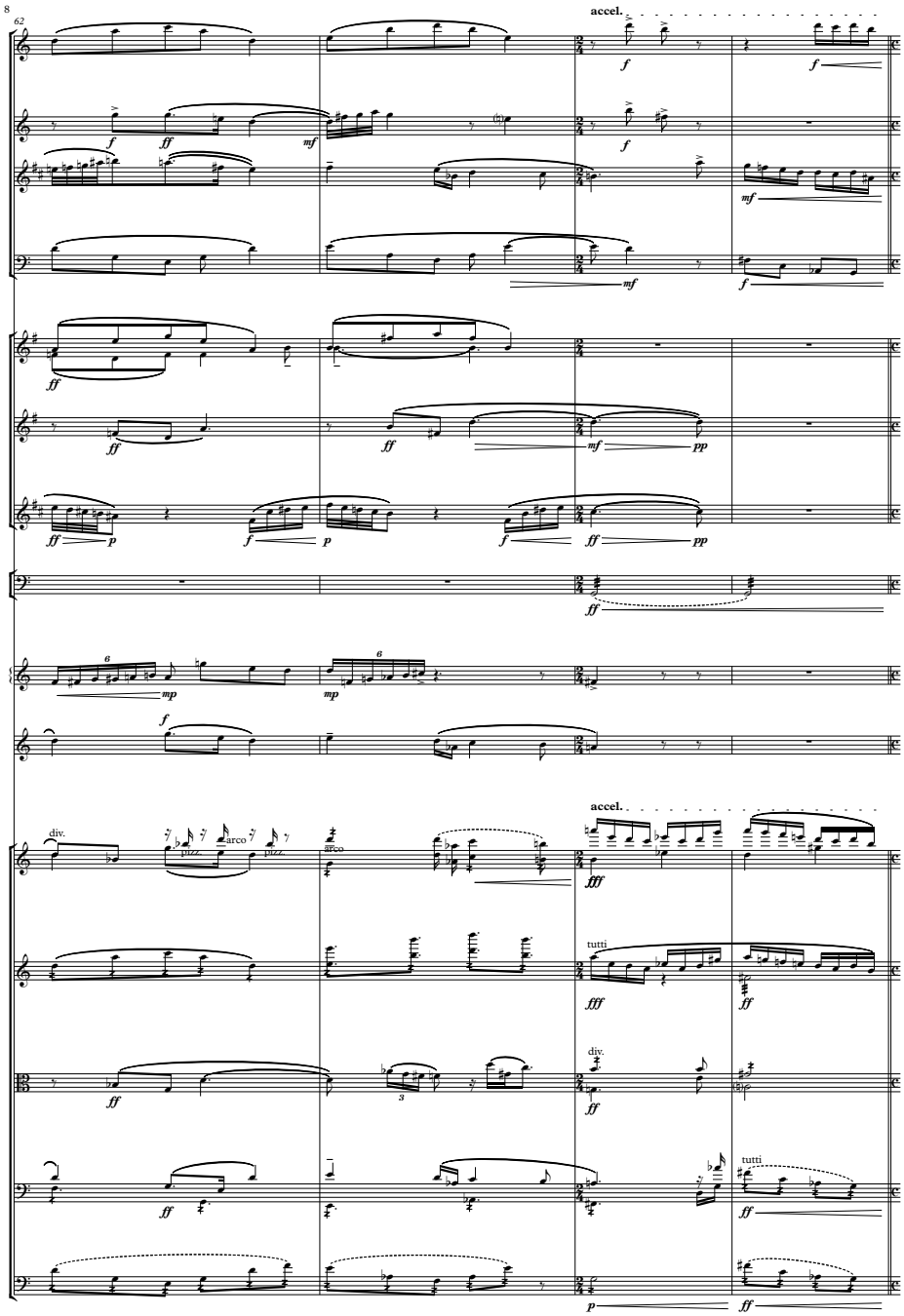


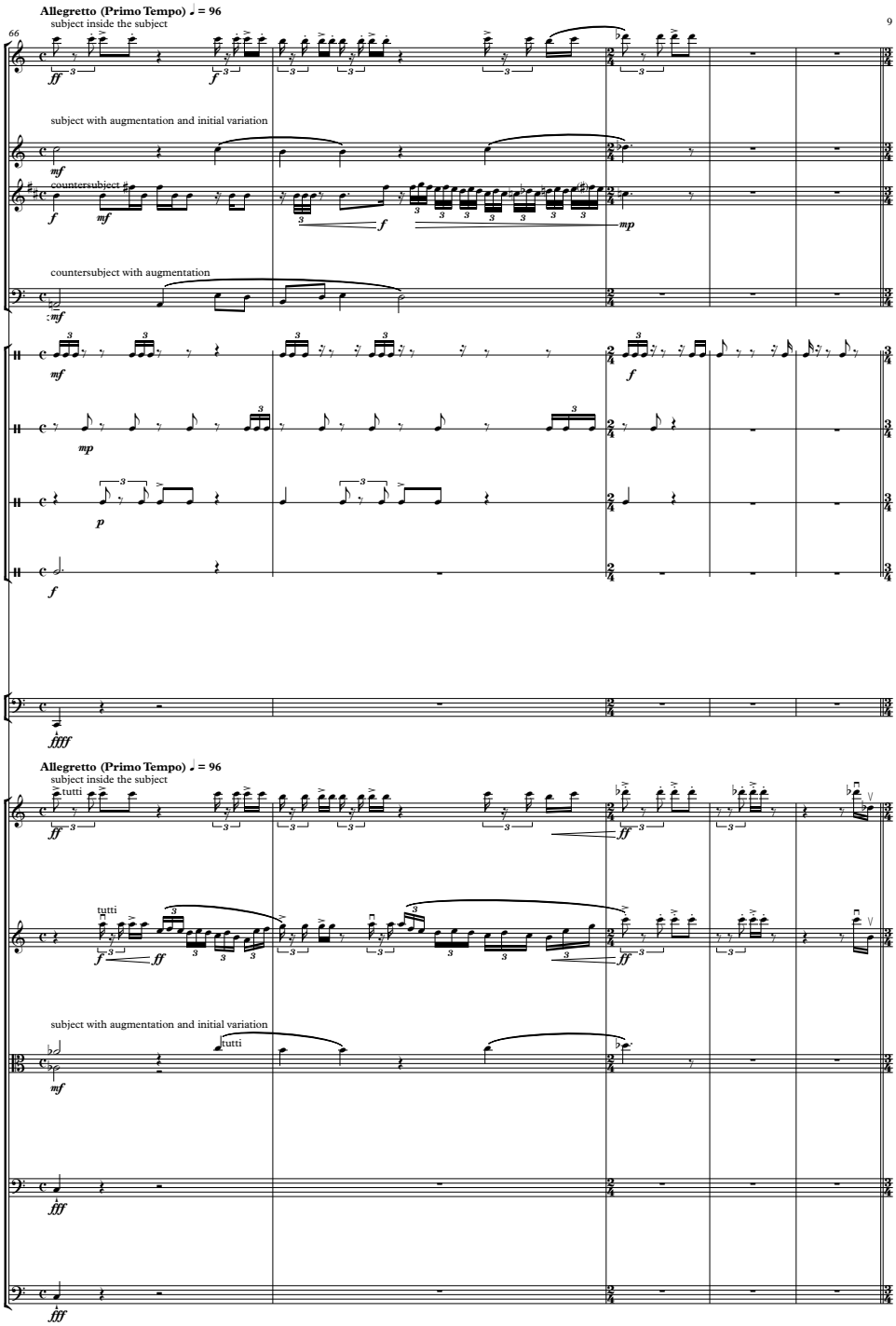


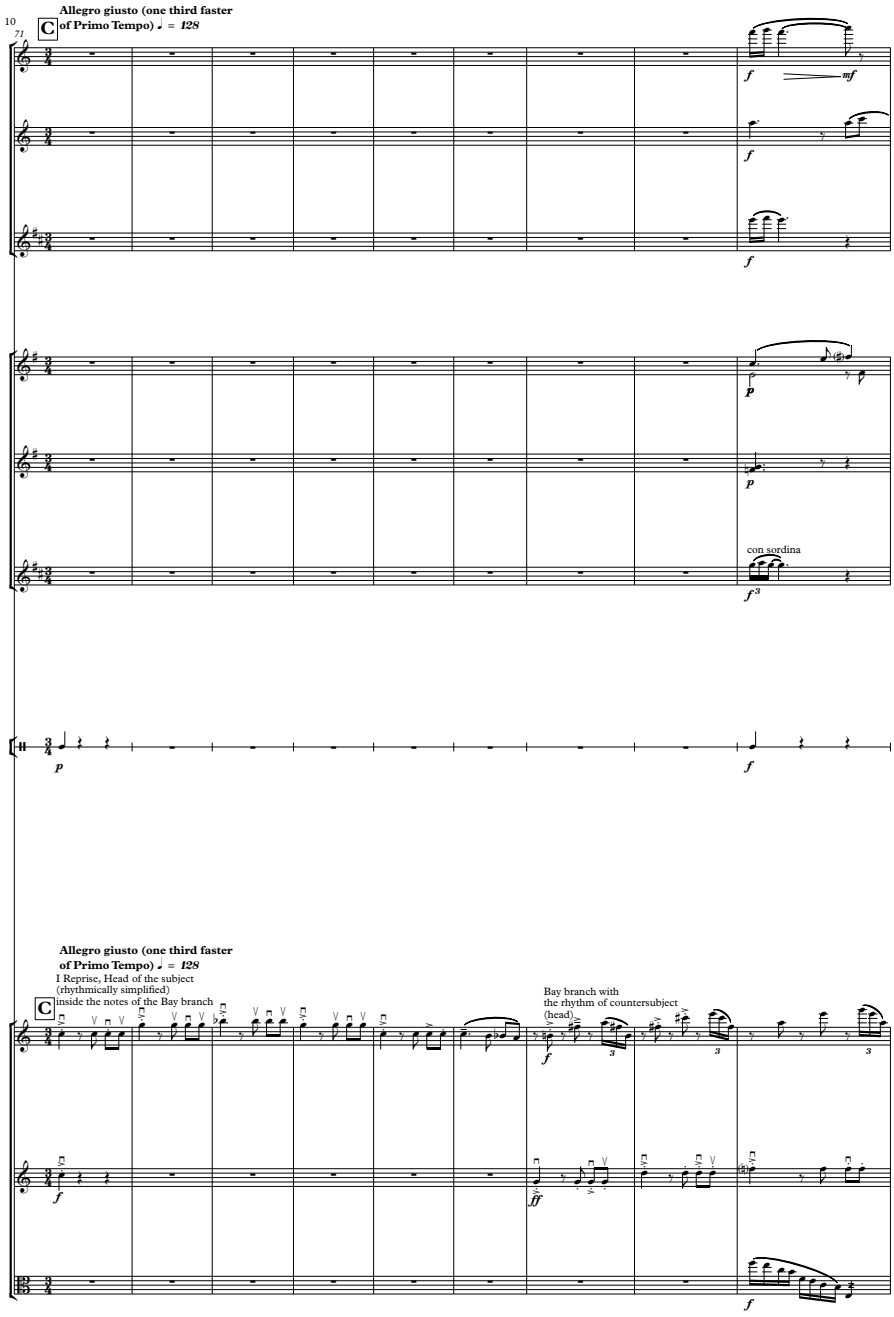

Doppio (più lento)
Largo ♩ = 48
44
5
Doppio (più lento)
Largo ♩ = 48

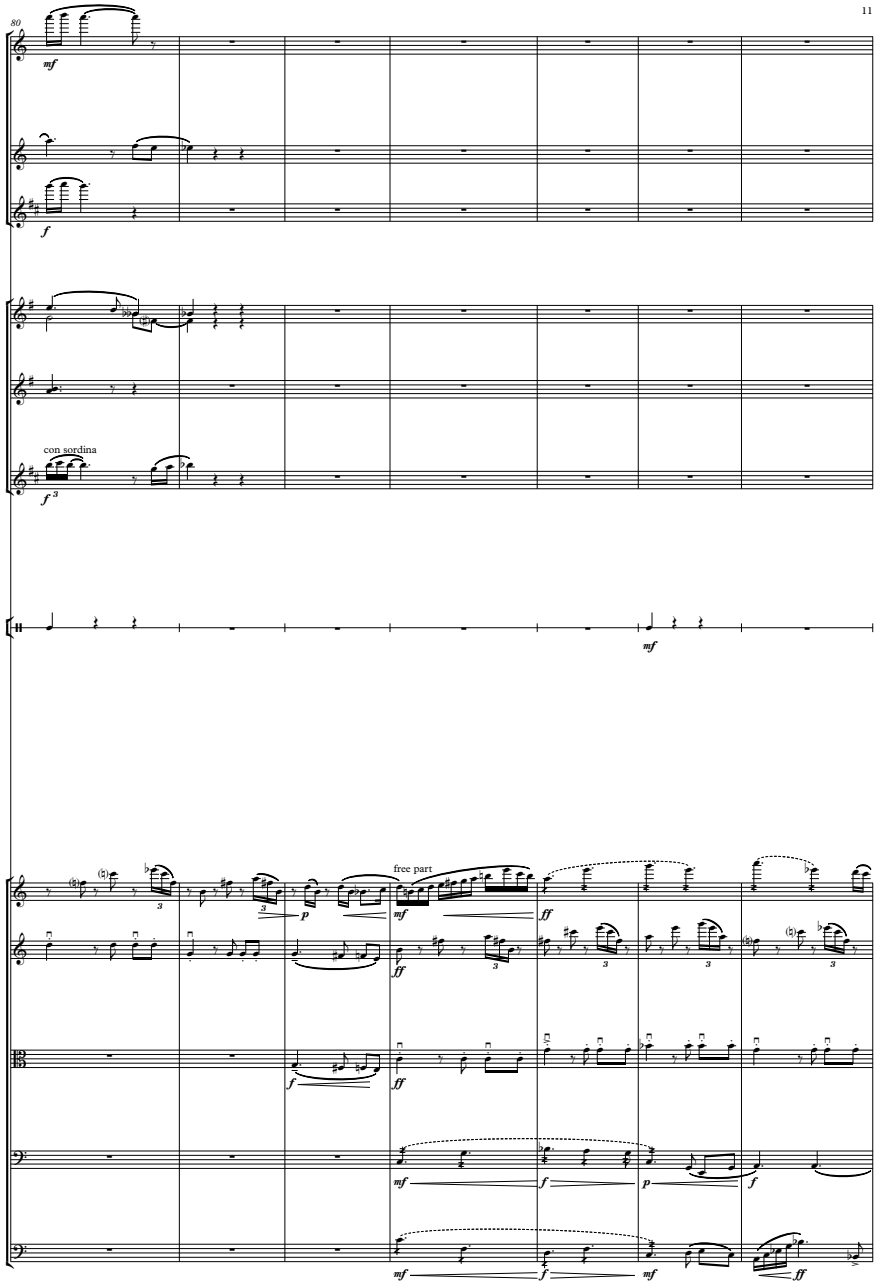

6
56
accel.
accel.

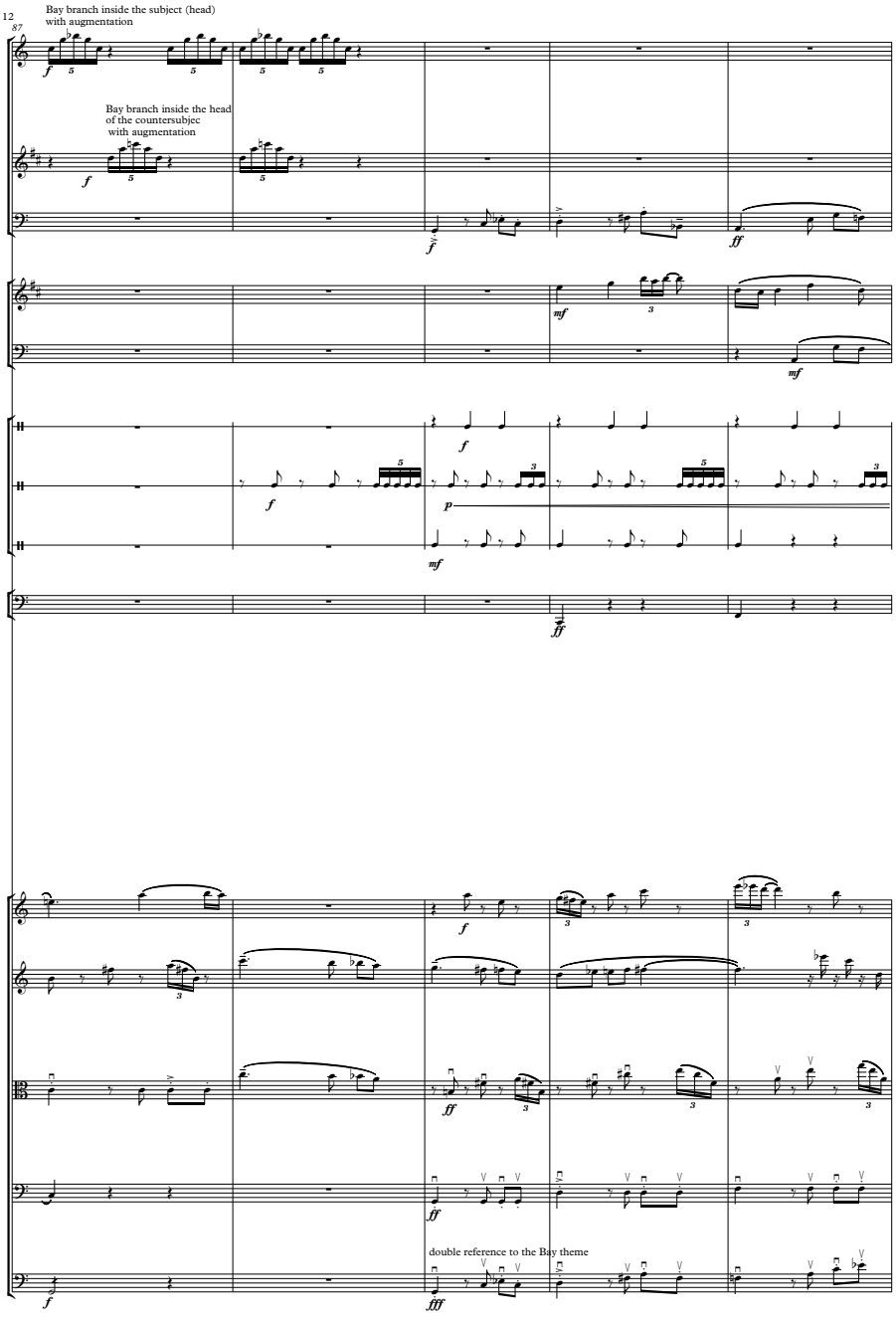

I Divertimento (Bay Branch)
B
Andante (one third faster previous time) ♩ = 64
7
60
B
Andante (one third faster previous time) ♩ = 64
div.
pizz.
arco

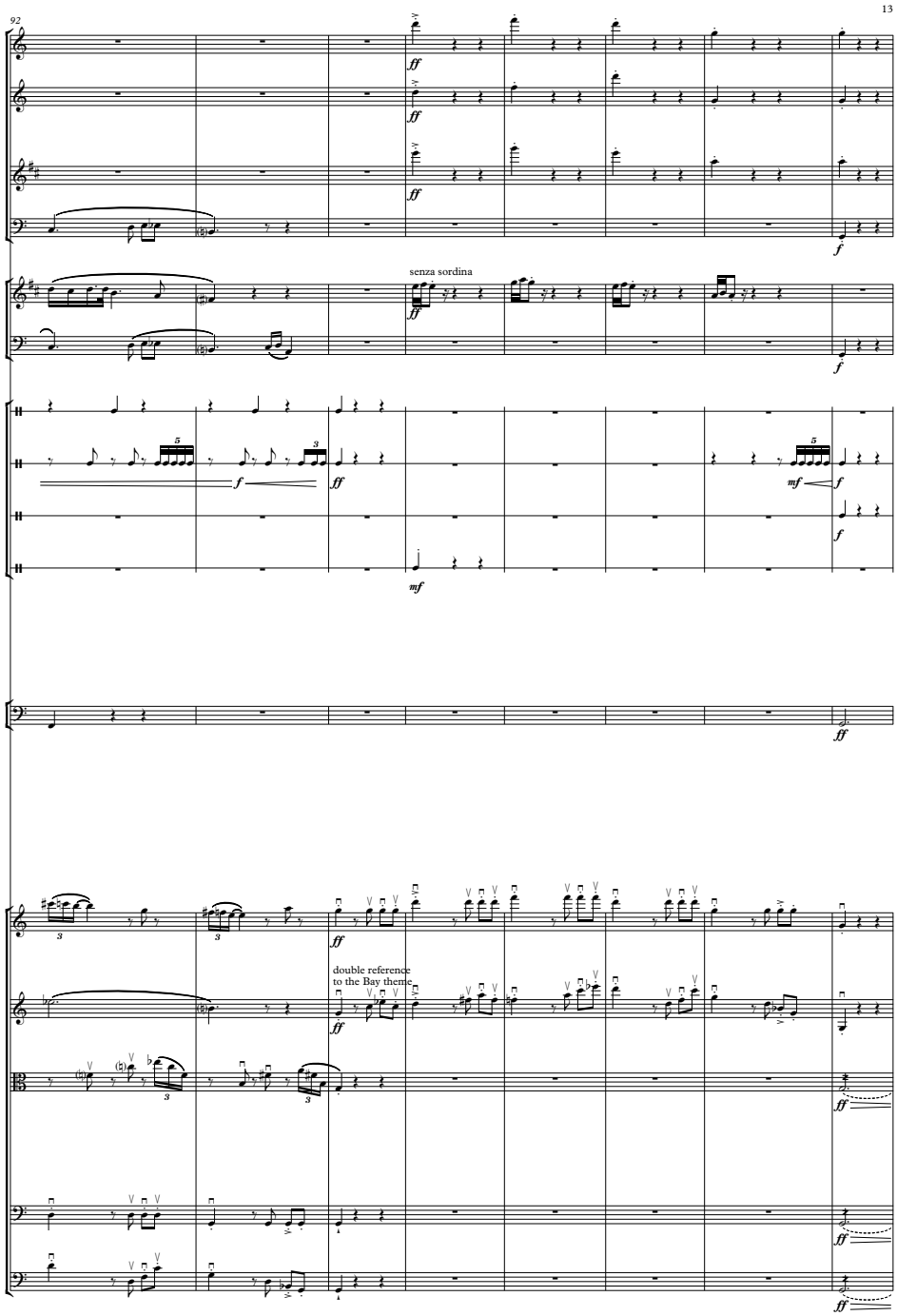

8
62
accel.
f
ff
mf
p
pp
mp
6
div.
pizz.
arco
tutti
fff
3
accel.

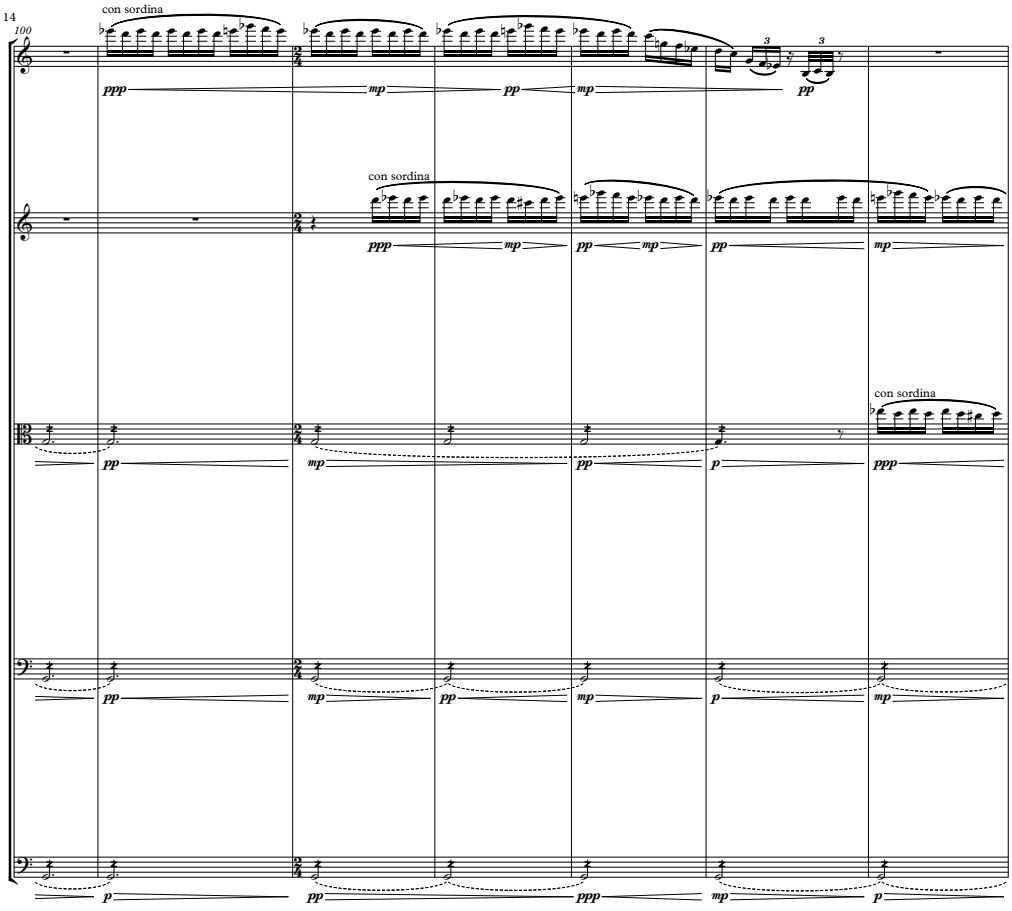

Allegretto (Primo Tempo) ♩ = 96
subject inside the subject
66
9
subject with augmentation and initial variation
countersubject
countersubject with augmentation
Allegretto (Primo Tempo) ♩ = 96
subject inside the subject
tutti
subject with augmentation and initial variation
tutti

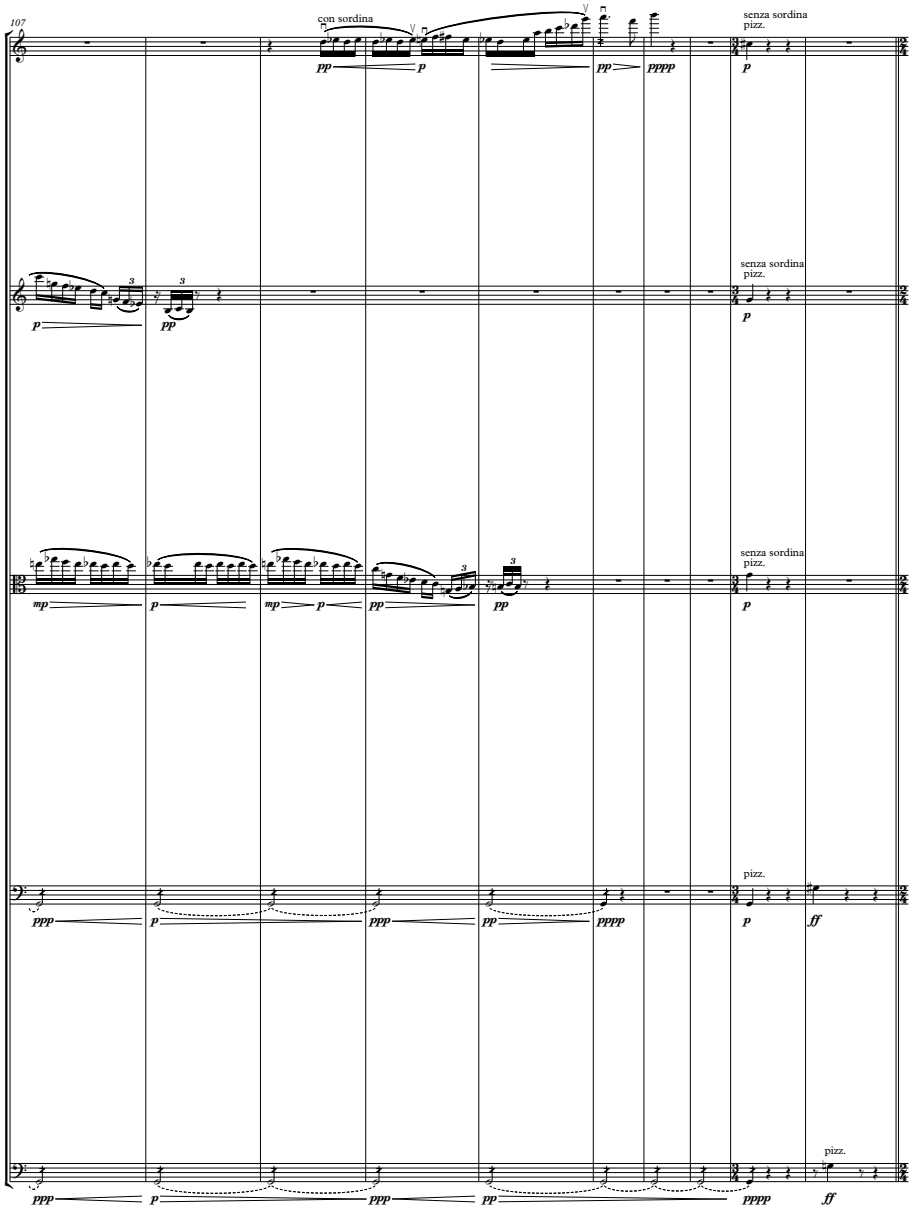

10
71
C
Allegro giusto (one third faster
of Primo Tempo) ♩ = 128
f
mf
f
f
p
p
con sordina
f 3
p
f
Allegro giusto (one third faster
of Primo Tempo) ♩ = 128
I Reprise, Head of the subject
(rhythmically simplified)
C
inside the notes of the Bay branch
Bay branch with
the rhythm of countersubject
(head)
f
3
3
3
f
ff
f


80
mf
f
con sordina
f 3
mf
free part
mf
ff
p
ff
f
ff
mf
f
p
f
mf
f
mf
ff


12
87
Bay branch inside the subject (head)
with augmentation
Bay branch inside the head
of the countersubjec
with augmentation
double reference to the Bay theme


92
13
senza sordina
double reference
to the Bay theme


14
100
con sordina
con sordina
con sordina

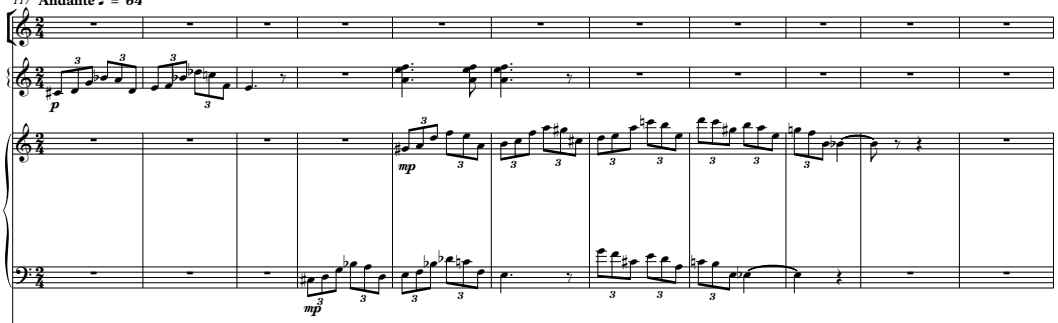

107
con sordina
senza sordina
pizz.
senza sordina
pizz.
senza sordina
pizz.
pizz.
pizz.

16

II Divertimento
(Olive branch)
Piano and vibraphone have
the discrete hypergesture,
while strings, trombone and
voice have the continuous
one with glissando

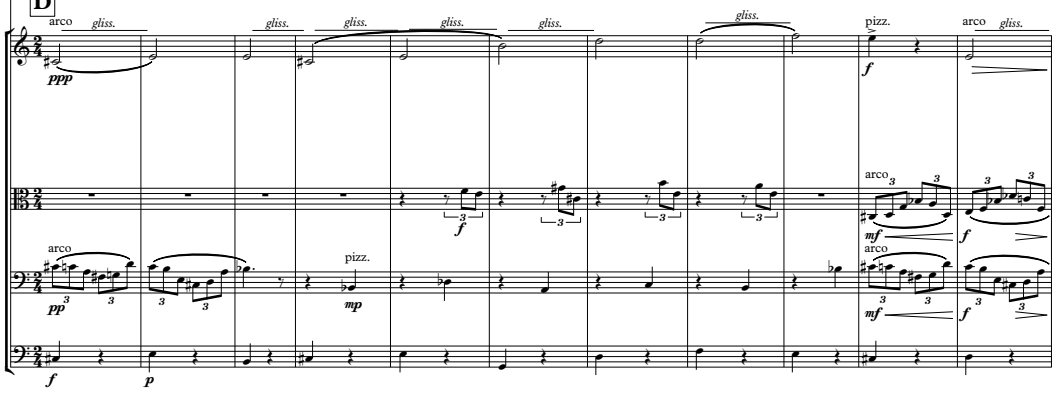
D

117 **Andante** ♩ = *64*

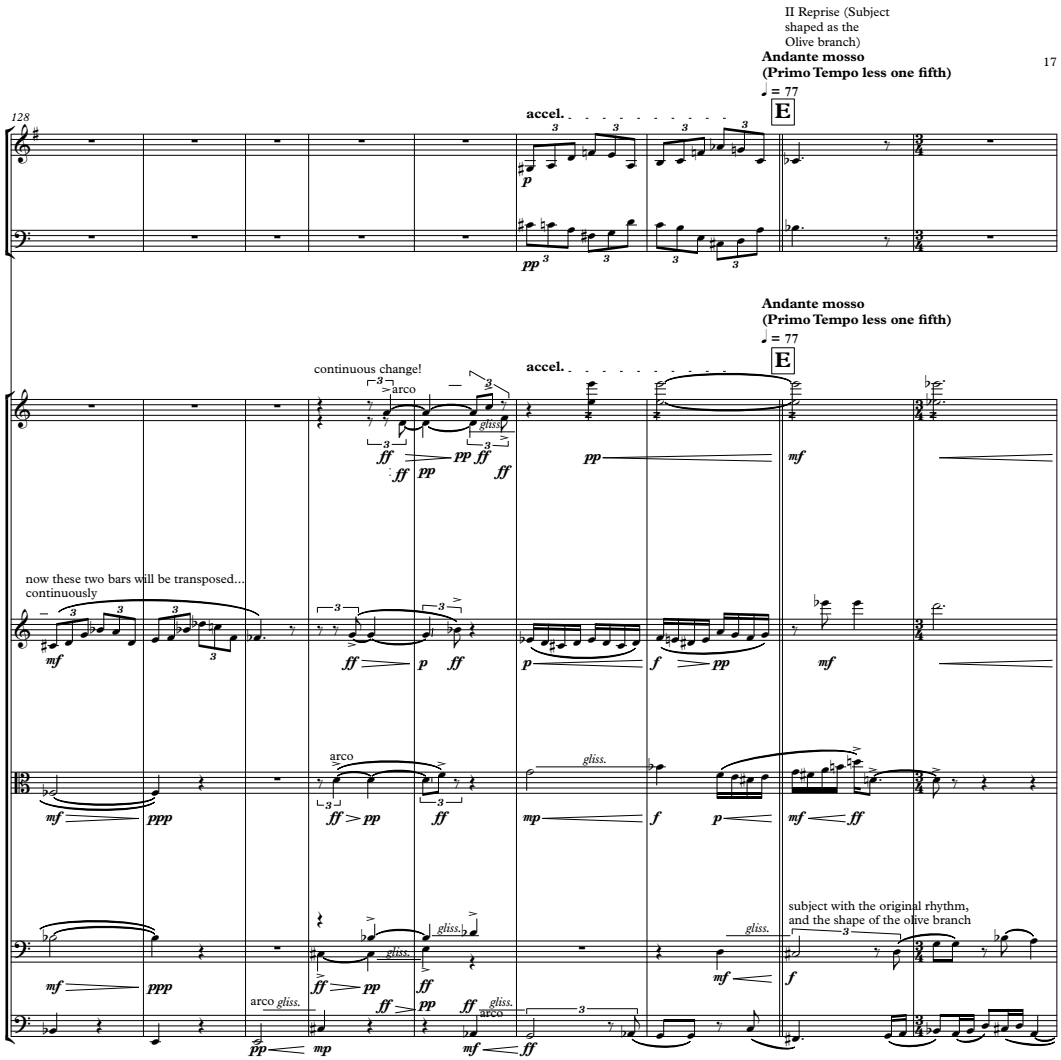


Andante ♩ = *64*

D

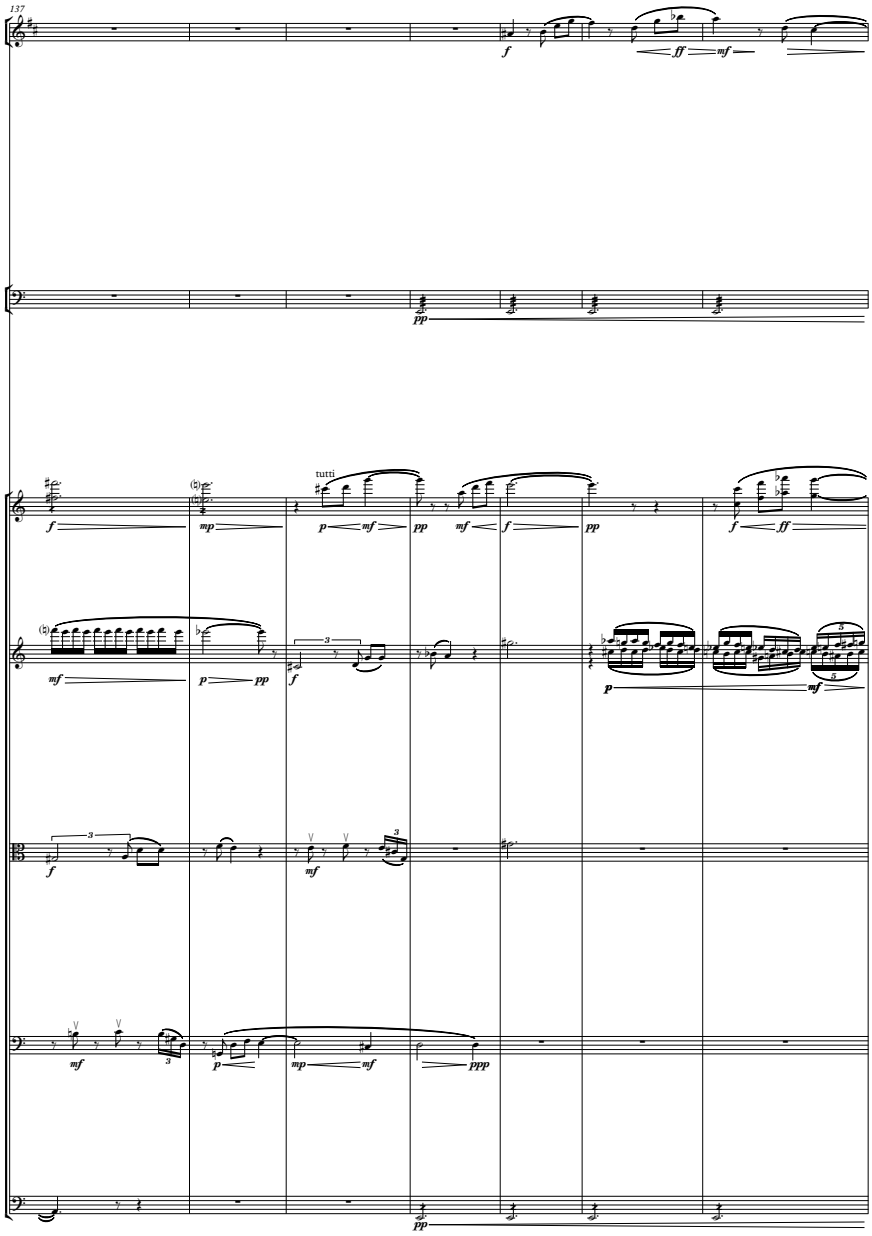


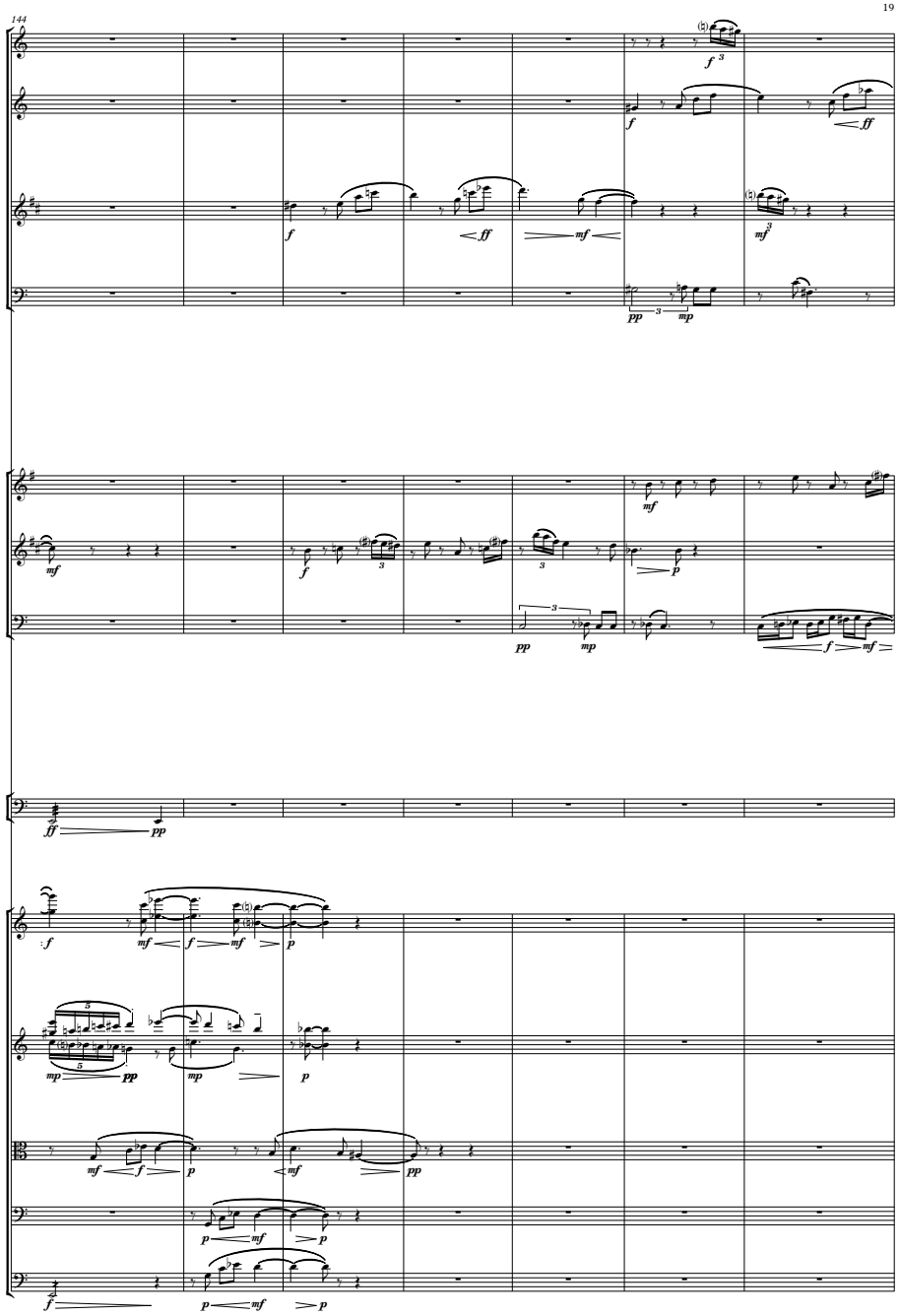
II Reprise (Subject
shaped as the
Olive branch)

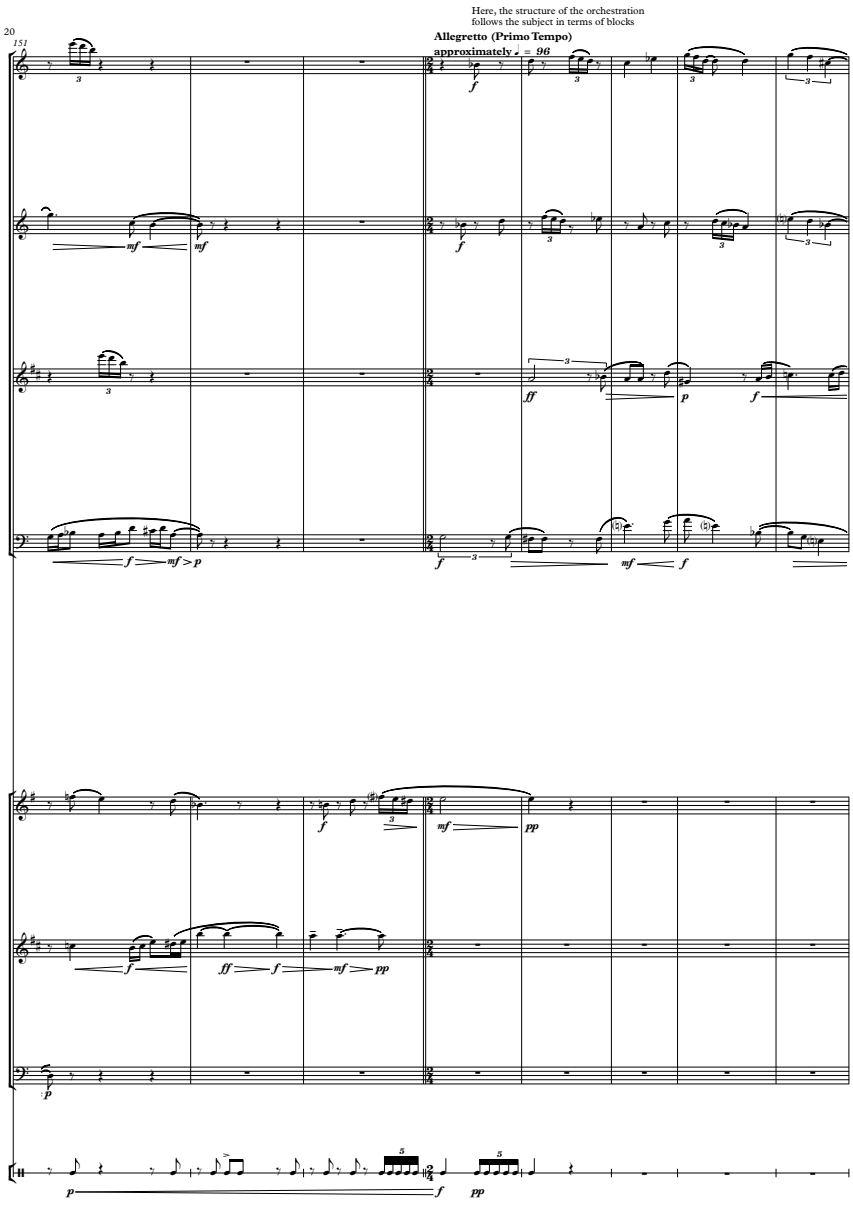


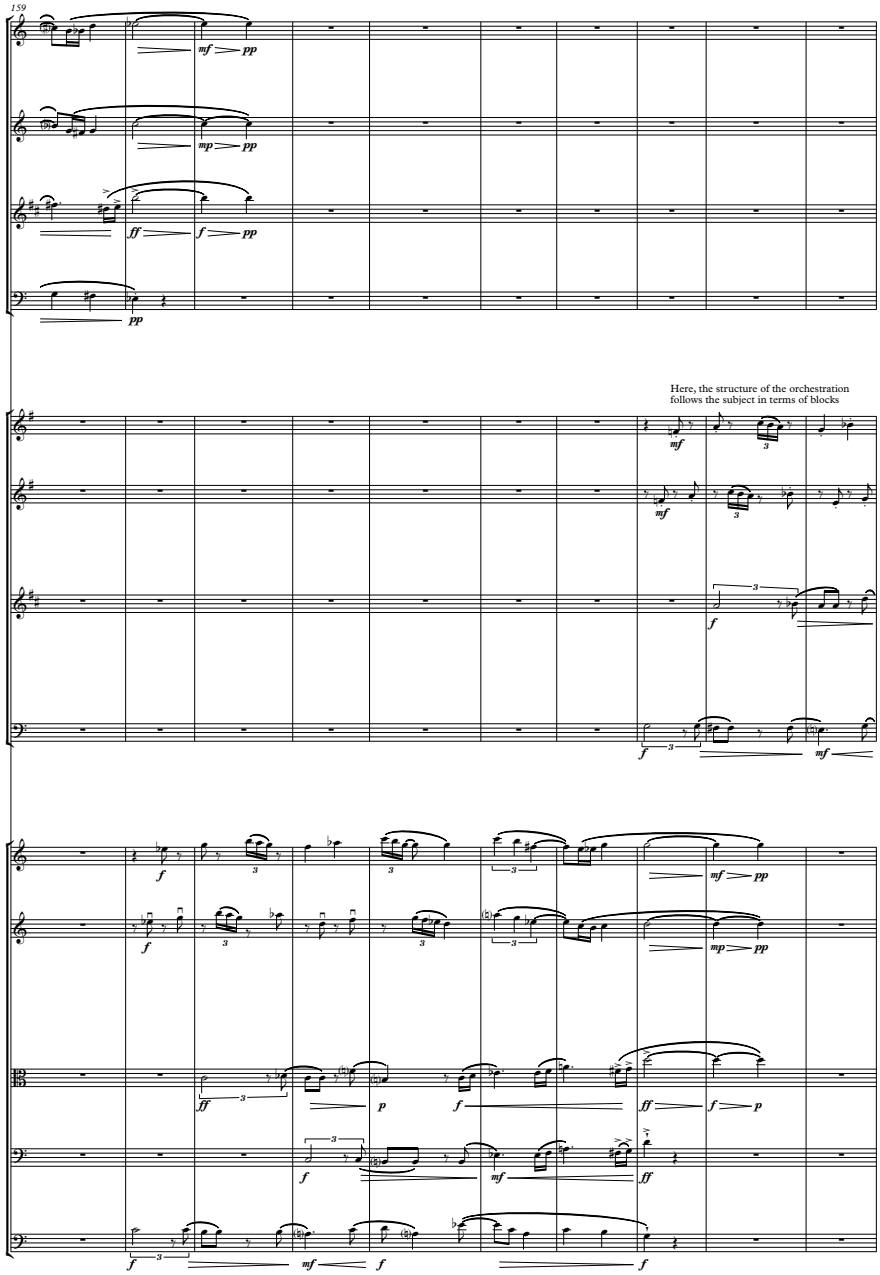
18

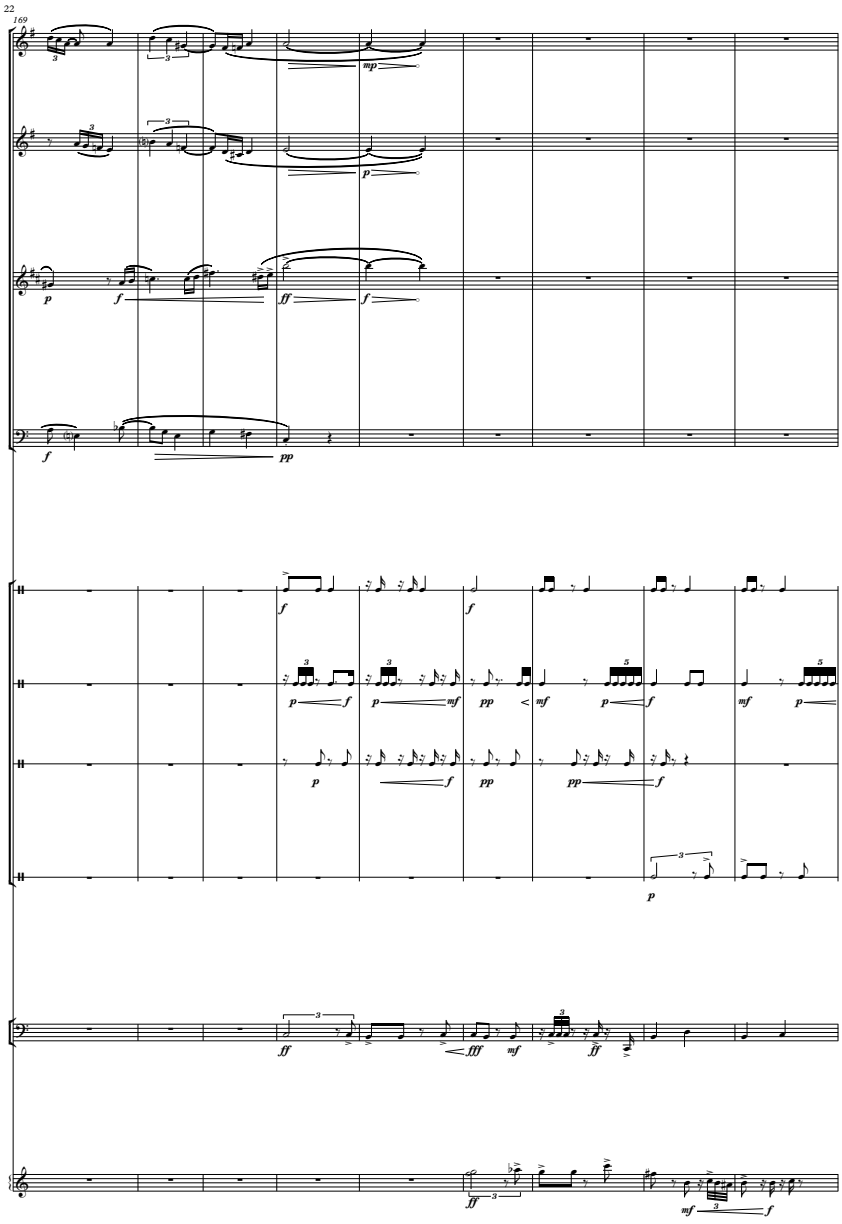
subject with the rhythmic
simplification, and shaped by
the olive branch

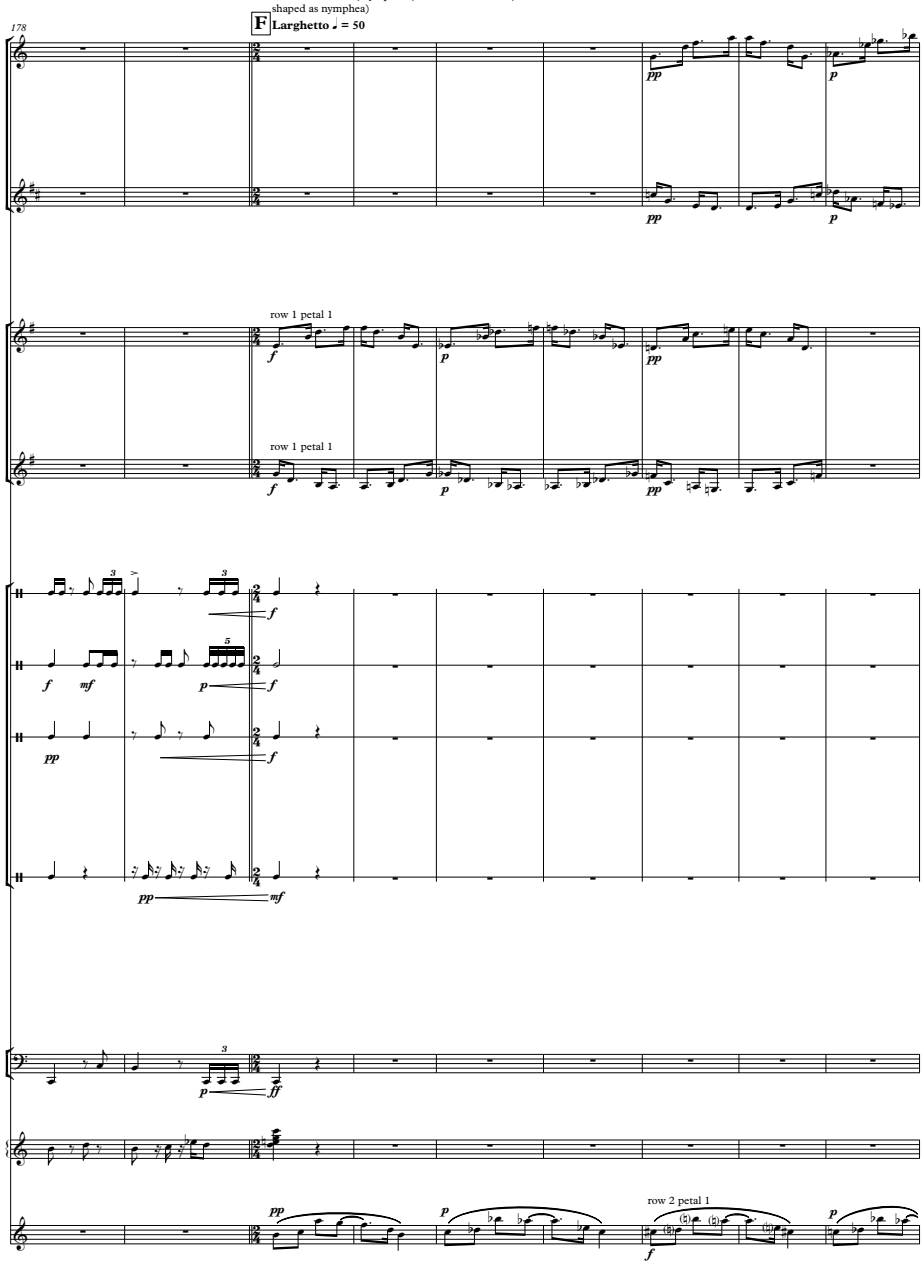


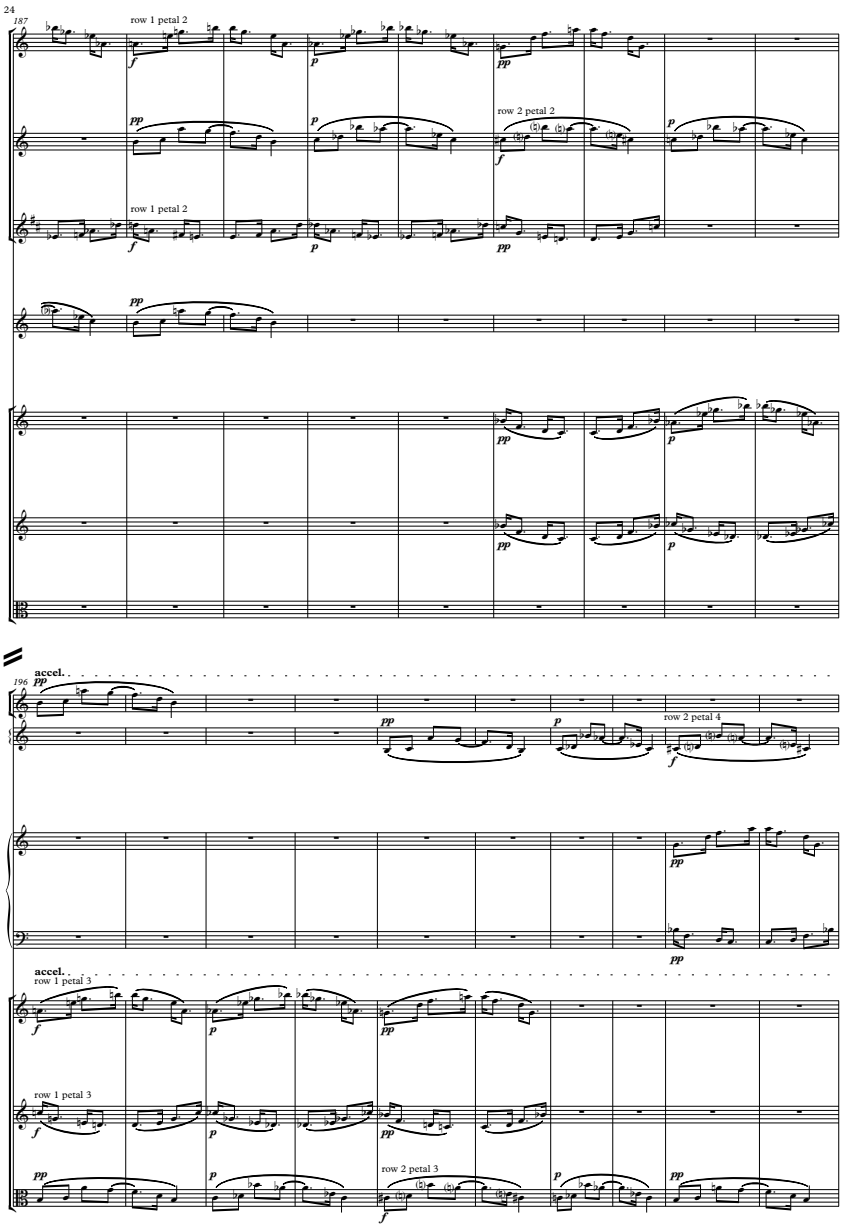

144

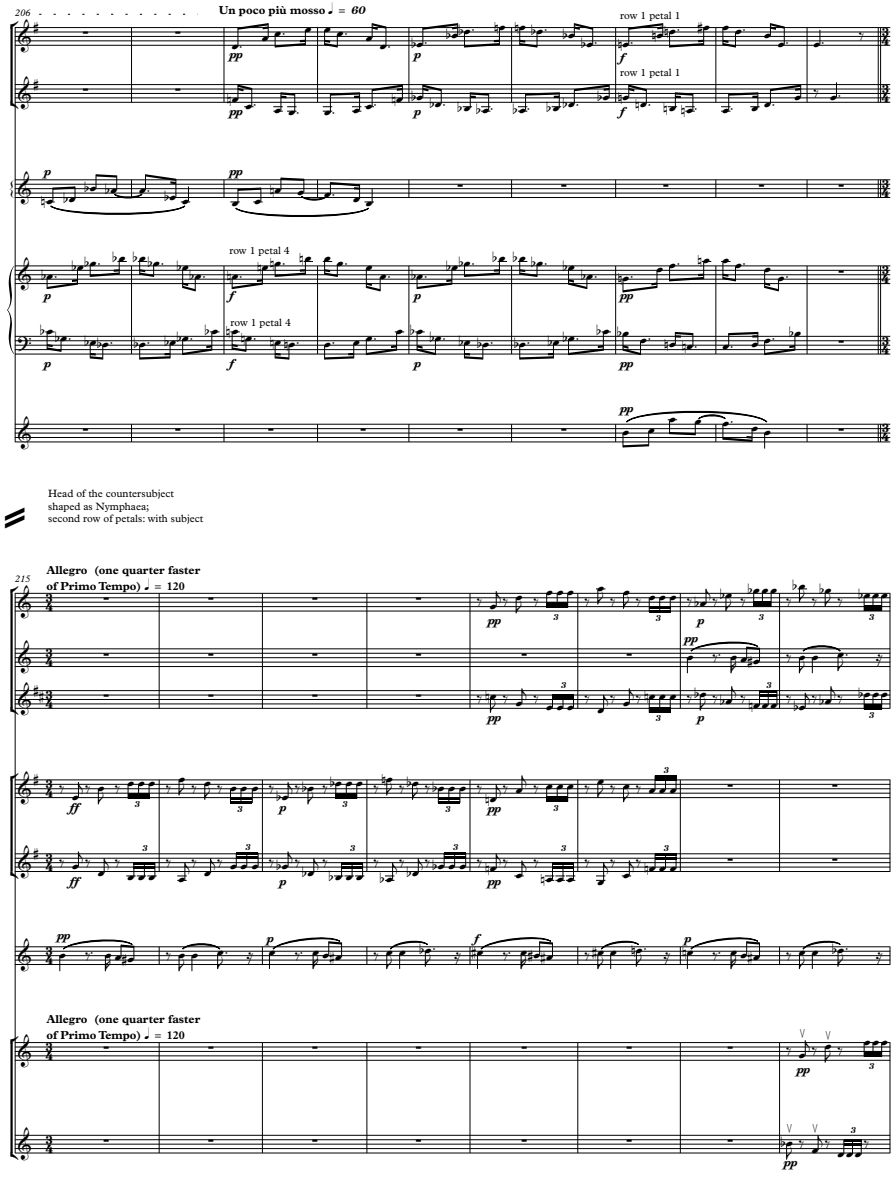

20
151
Here, the structure of the orchestration
follows the subject in terms of blocks
Allegretto (Primo Tempo)
approximately ♩ = 96

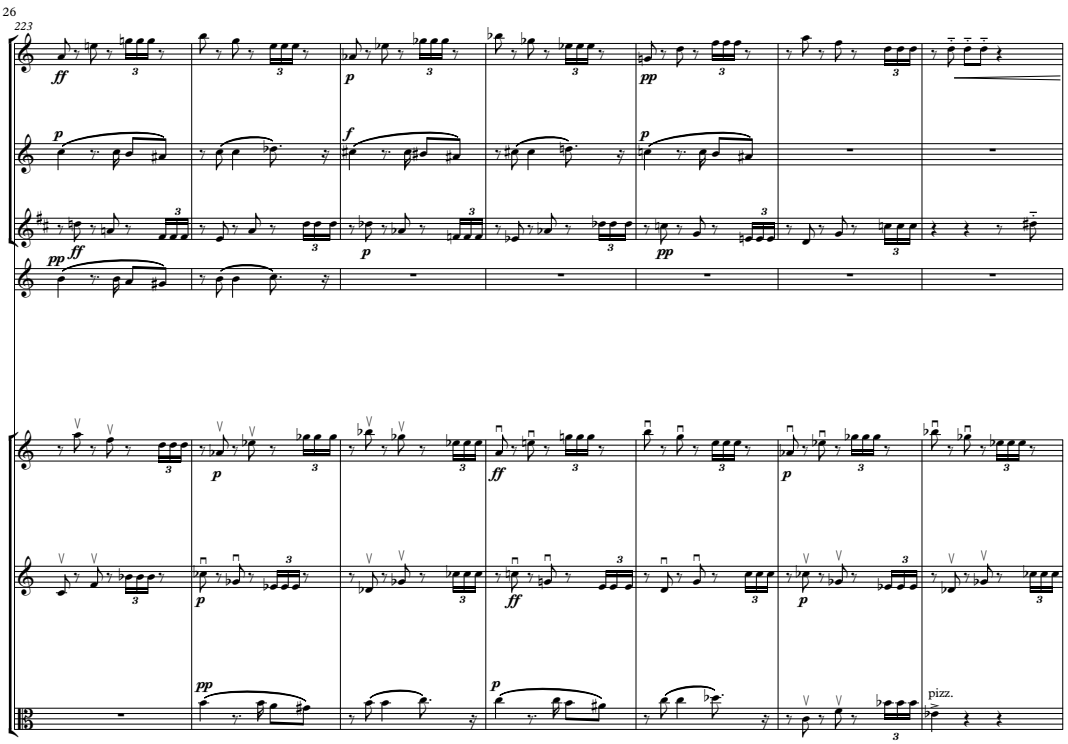

159
Here, the structure of the orchestration
follows the subject in terms of blocks


22
169

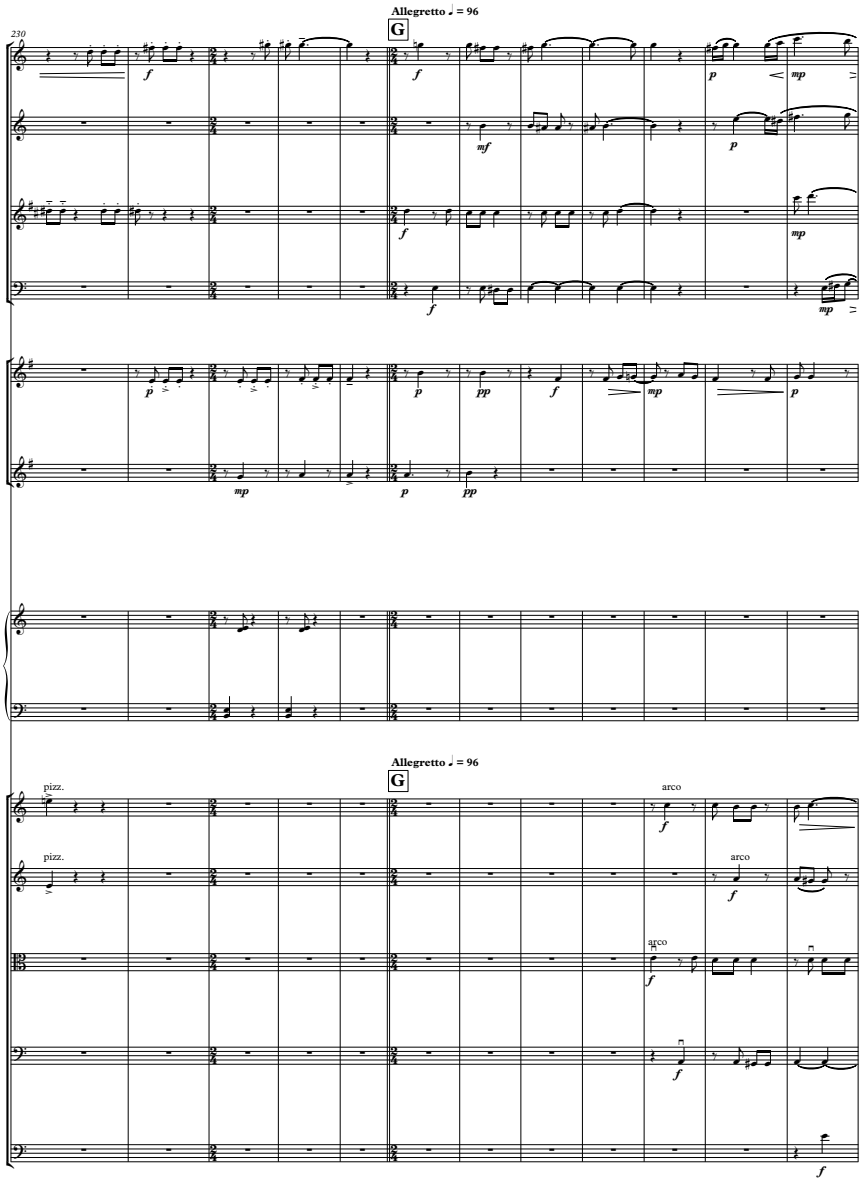

178
F
Larghetto ♩ = 50
row 1 petal 1
row 1 petal 1
row 2 petal 1

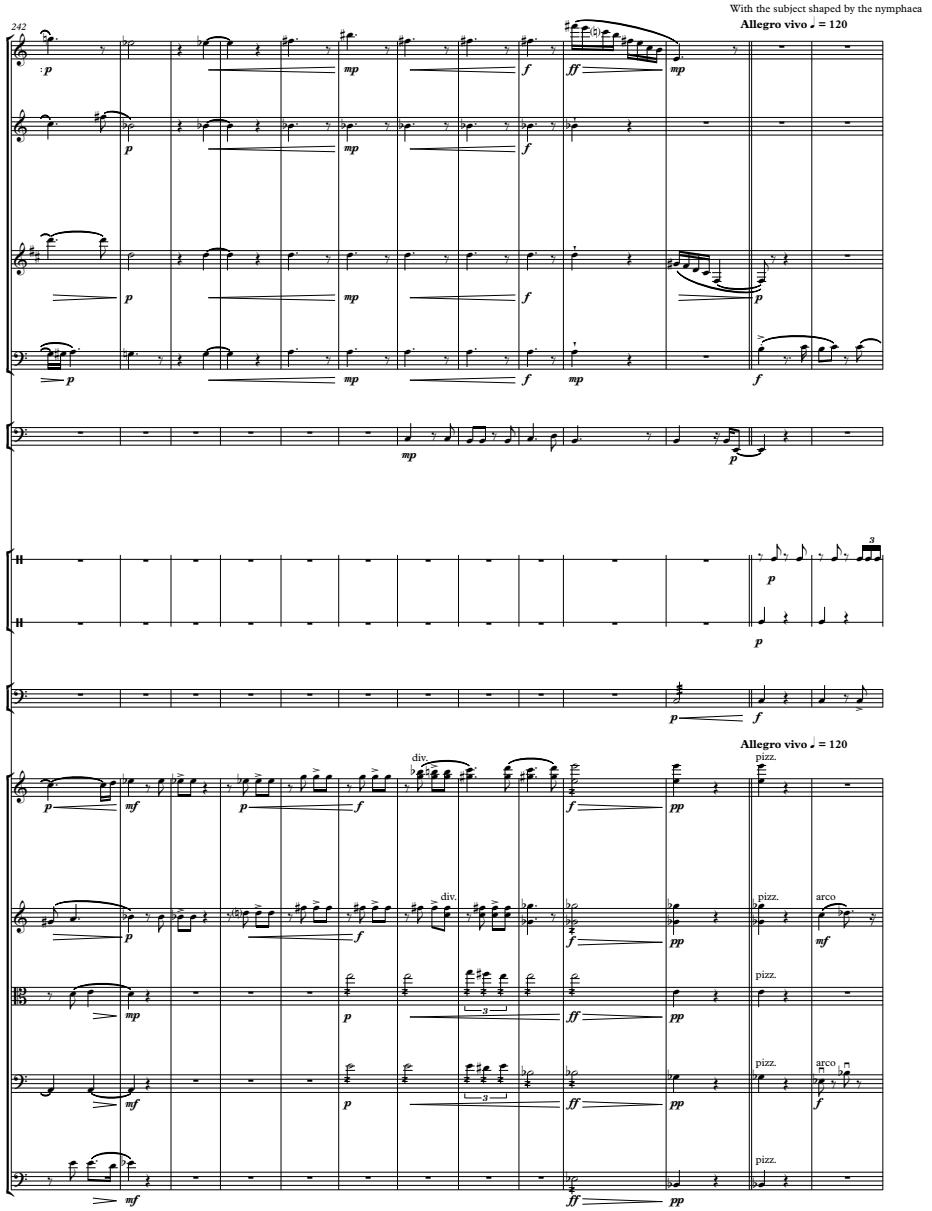

24
187
row 1 petal 2
row 2 petal 2
row 1 petal 2
196
accel.
row 2 petal 4
accel.
row 1 petal 3
row 1 petal 3
row 2 petal 3

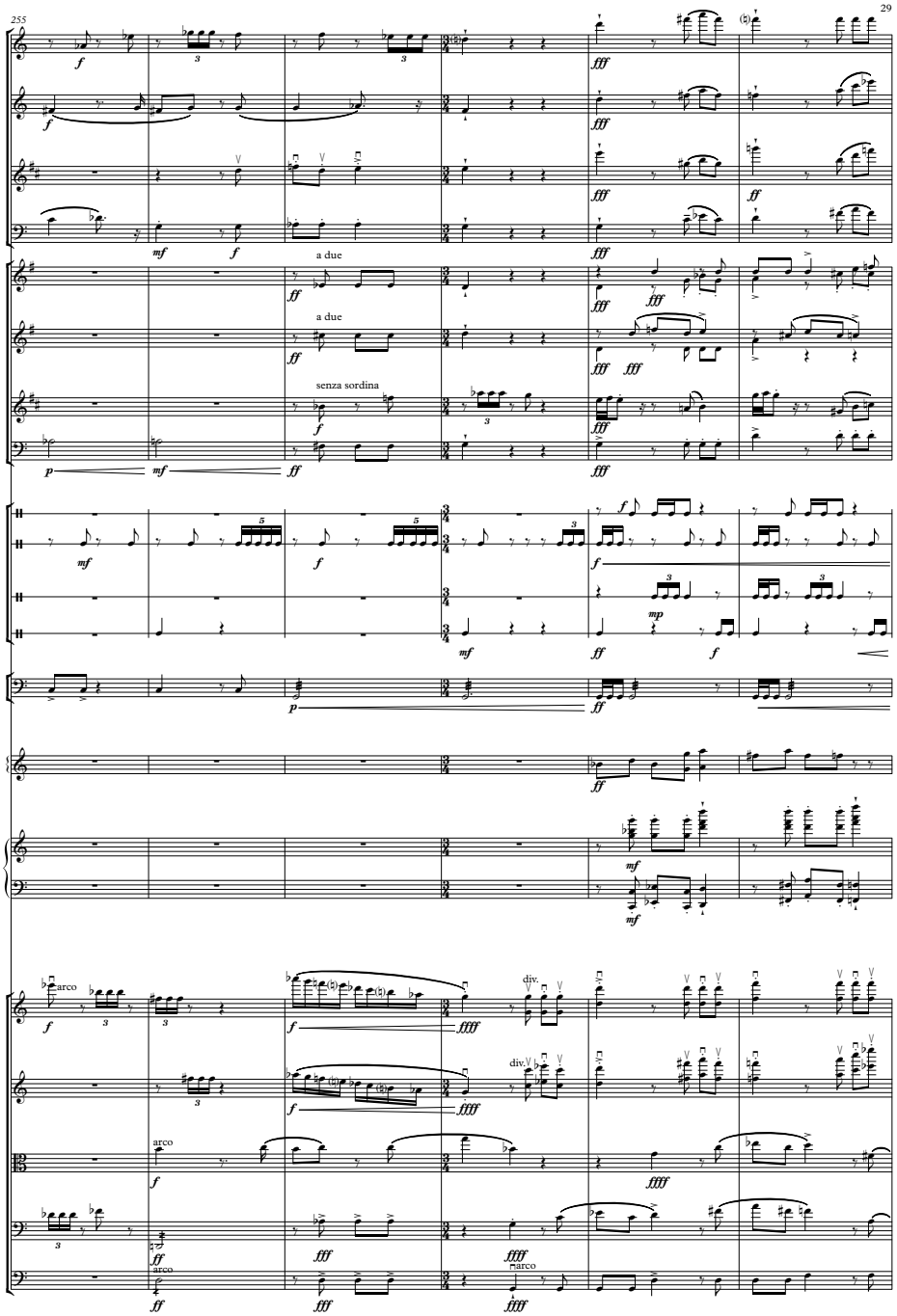

206
Un poco più mosso ♩ = 60
row 1 petal 1
row 1 petal 1
row 1 petal 4
row 1 petal 4
Head of the countersubject
shaped as Nymphaea;
second row of petals: with subject
215
Allegro (one quarter faster
of Primo Tempo) ♩ = 120
Allegro (one quarter faster
of Primo Tempo) ♩ = 120

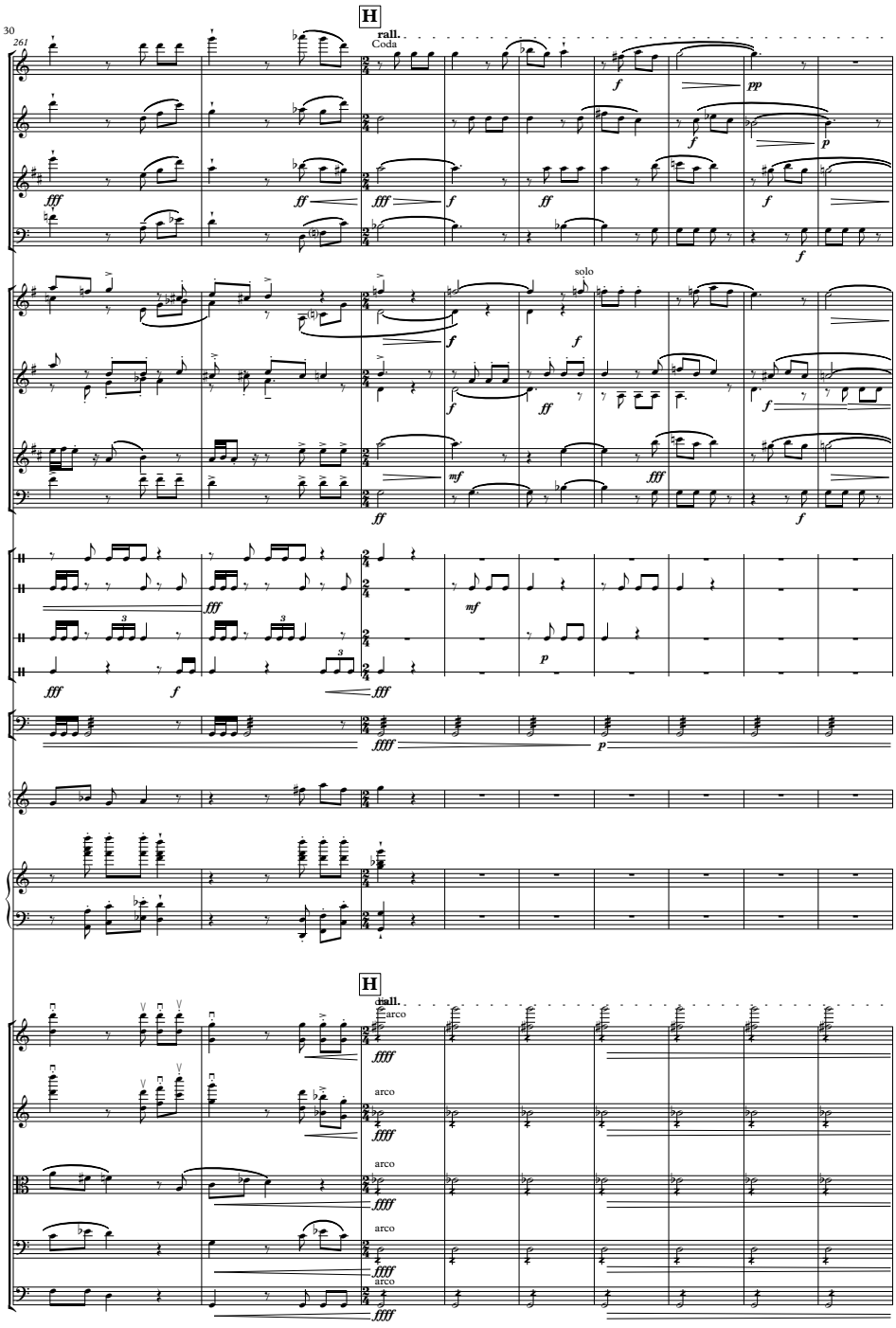

26
223
pizz.

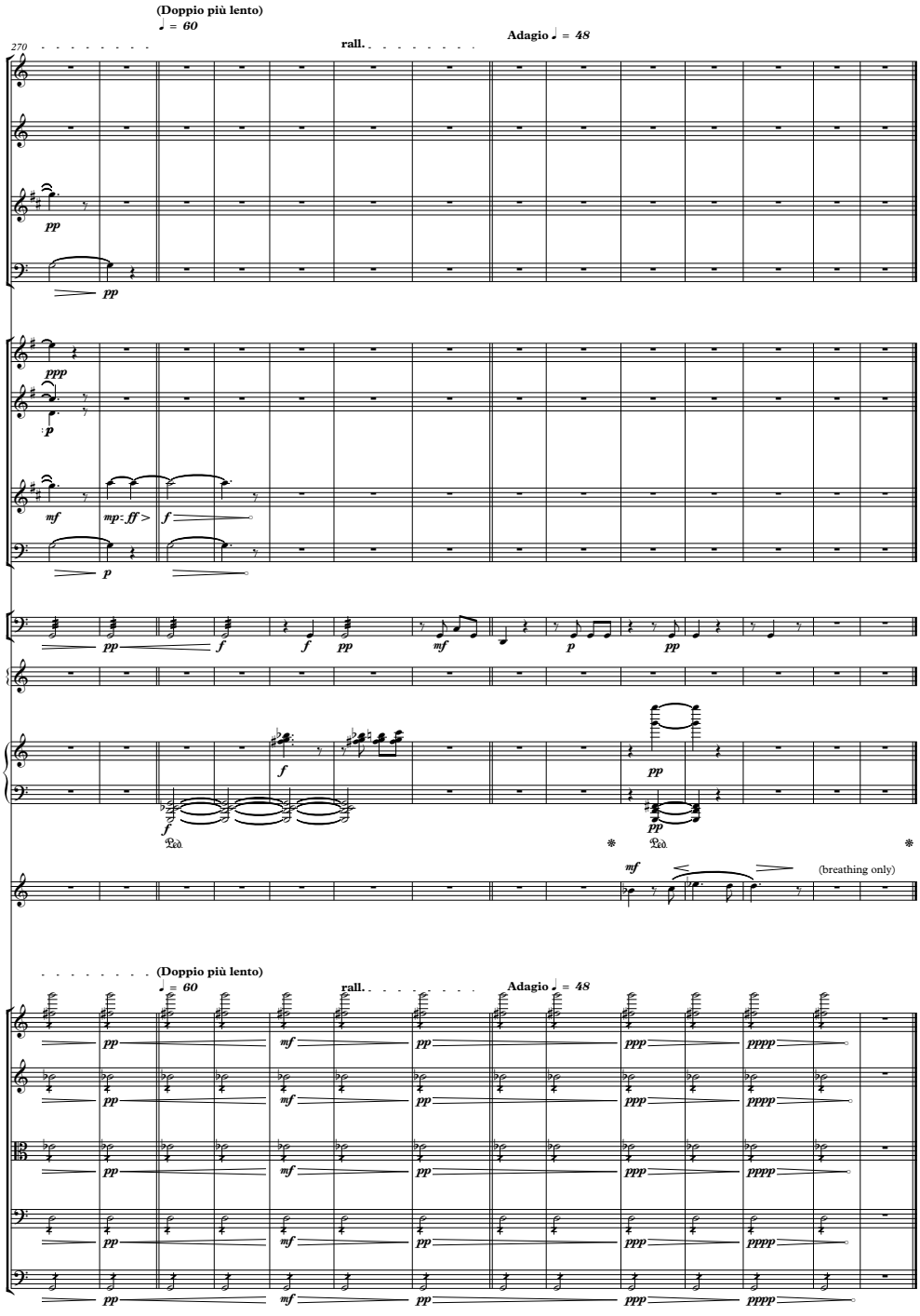
III Reprise and Stretti
(then: with
Nymphaea shape)




With the subject shaped by the nymphaea
242
Allegro vivo ♩ = 120
Allegro vivo ♩ = 120
div.
pizz.
arco


255
29
a due
a due
senza sordina
arco
div.
arco


30
261
H
rall.
Coda
solo
H
rall.
arco


(Doppio più lento)
♩ = 60
270
rall.
Adagio ♩ = 48
pp
ppp
p
mf
mp
ff
f
(breathing only)
Ped.
(Doppio più lento)
♩ = 60
rall.
Adagio ♩ = 48
pp
mf
ppp
pppp